



**UNITED STATES ENVIRONMENTAL
PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105**



**STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HI 96801-3378**

Mark Manfredi
Red Hill Regional Program Director
Naval Facilities Hawaii
400 Marshall Road
Joint Base Pearl Harbor Hickam, Hawaii 96860

**Re: Comments on Ongoing Work to Satisfy the Red Hill Bulk Fuel Storage Facility
("Facility") Administrative Order on Consent ("AOC") Statement of Work
requirements 7.1.3 (Groundwater Flow Model Report) and 7.2.3 (Contaminant Fate
and Transport Report).**

Dear Mr. Manfredi:

The U.S. Environmental Protection Agency ("EPA") and Hawaii Department of Health ("DOH"), collectively the "Regulatory Agencies", appreciate the significant efforts undertaken by the U.S. Department of the Navy ("Navy") and its contractors to satisfy the AOC Statement of Work requirements referenced above.

The Navy has hired experts in groundwater modeling, obtained assistance from the U.S. Geological Survey via an interagency agreement, and has convened numerous meetings with the Regulatory Agencies and external subject matter experts such as the Department of Land and Natural Resources and Honolulu Board of Water Supply.

The primary goal of the modeling effort in progress by the Navy and its consultants should be to develop tools that help evaluate and predict the risk posed to groundwater and drinking water sources from past and potential future releases from the Facility. As with any groundwater modeling effort, the utility of the developed models to support decision making relies on both the quality and resolution of data used to develop the models and the rigor and performance of the calibration.

Recently, the Regulatory Agencies hired additional technical specialists to advise us on some of the more complex aspects of this work. These additional specialists supplement our current team of consultants, a University of Hawaii expert, and other in-house experts. Based on the observations and input from these specialists over the last few months, the Regulatory Agencies have the following overarching concerns:

1. The Navy and its consultants appear to be drawing conclusions prematurely about key aspects of the model that strongly influence groundwater flow and contaminant fate and transport, well before the development and calibration of the interim model has been completed and reviewed.
2. The Navy and its consultants' current approach to simplifying the hydro-stratigraphy within the interim model may not render a conservative evaluation of potential groundwater flow and contaminant migration.
3. Characteristics of the underlying conceptual site model presented by the Navy and its consultants are not sufficiently supported by data collected at the site.
4. The Navy and its consultants have not presented a strategy or framework for evaluating the uncertainty associated with results obtained from the model.
5. The Navy and its consultants' initial analysis of Non-Aqueous Phase Liquid transport, fate and transformation in the unsaturated zone is not likely conservative and appears to be inconsistent with data collected at the site.

Given these concerns, the Navy and its consultants should proceed carefully to develop a model that accurately reflects the current state of environmental data present and considers the comments and observations of our technical experts. The issues and concerns raised by our technical experts are included in attachments to this letter.

The groundwater flow model and contaminant fate and transport model should be reliable tools that ultimately inform and support key decisions at the Facility and in the surrounding area. The quality of these decisions, such as tank upgrade selection, sentinel well placement, and contingency planning, will be significantly improved by a modeling framework that is scientifically rigorous and able to withstand legitimate scrutiny.

Please feel free to contact us if you would like to discuss this matter further.

Sincerely,



Omer Shalev
Project Coordinator
EPA Region 9 Land Division

Roxanne Kwan
Interim Project Coordinator
DOH Solid and Hazardous Waste Branch

Attachments:

Memos and comments to Ms. Grange, Mr. Pallarino and Ms. Tu from:
AQUI-VER
S.S. Papadopoulos & Assoc., Inc. (SSP&A)
Dr. Don Thomas, University of Hawaii
Mr. Robert Whittier, Hawaii Department of Health, Safe Drinking Water Branch

cc: Captain Richard D. Hayes III, Navy (via email)
Janice Fukumoto, NAVFAC Hawaii (via email)

Ms. Fenix Grange, Program Manager
Hazard Evaluation and Emergency Response Office
Hawaii Department of Health
2385 Waimano Home Road
Pearl City, HI 96782

February 15, 2018

Subject: Comments on the State of the Conceptual Site Model and Related Evaluations for the Navy
 Red Hill Tank Farm Facility, Pearl City, Hawai'i

Dear Ms. Grange:

As requested, I have prepared these comments on the current state of the conceptual site model (CSM) and related evaluations for the Navy Red Hill Tank Farm Facility, Pearl City, Hawai'i. Because I have only been working on this project since December 2017, there may be elements of the Navy's work of which I am unaware that may address some of the issues I raise here. Further, based on our meeting with the Navy on February 8, their technical team may be in the process of addressing some of the concerns raised by me, Robert Whittier, Don Thomas and Matt Tonkin. This review will keep to a relatively high level, as the details are extensive and not as important at this point as are these key observations. My main focus is on jet fuel transport and risk aspects of the CSM.

A related and critical issue is the absence of simple and seamless access to data and existing reports. There does not appear to be any library catalog of existing reports, data, and technical support materials like mapping layers, etc. that is available to the DOH/EPA team. Without that data and information, it is difficult for me and our other experts to fully evaluate scientific findings and conclusions by the Navy team. There are a few documents on the EPA Red Hill website, but nothing comprehensive and with no working digital data.

In summary, the CSM for the Red Hill facility appears to draw preliminary conclusions that are non-conservative, meaning it purports that a robustly protective subsurface hydrogeologic system exists into which a million of gallons of jet fuel could be released without any resultant groundwater damages. While this is an interim conclusion that may change, the Navy's data collection and CSM building seems to be skewed toward investigation of those elements that are protective, but not to the elements that are risk drivers. For instance, the continuity of fractures and bedding plane voids in this volcanic depositional system would be expected to allow for rapid and heterogeneous (likely unpredictable) contaminant transport of both jet fuel and the dissolved-phase plume it would create if it contacts groundwater.

The Navy CSM does not appear representative with respect to local area conditions around the Red Hill tank farm and ridge line. I have not seen a comprehensive analysis of the January 2014 jet fuel release from Tank 5, and the available investigation data points may not even allow for that. But this is one fundamental question for the CSM: a release of an estimated 27,000 gallons of jet fuel occurred, and the Navy has apparently not been able to define the outcomes and impacts of that release. Perhaps the Navy views it as unimportant because they do not observe large groundwater impacts. But that view is limited by a very sparse monitoring and gauging array in the Red Hill Ridge area. The CSM also does not seem to account for releases before 2014, the presence of which have material implications to the CSM as a whole. For instance, past releases will occupy some portion of the residual capacity of the subsurface materials, meaning that there will be less storage (buffering) capacity with respect to future releases.

The biggest single data gap at this time is of a comprehensive geologic analysis of the Red Hill Ridge area. This is a foundational aspect of the CSM and all related evaluations and modeling work. We believe the Navy team has done work in this category, but have not seen the details and cannot as yet understand their geologic model. The geologic evaluations would include items such as those shown in the Table below. Some of these elements have been presented by the Navy team, but most have not. Even for those that have been presented, we do not have access to the underlying data to confirm the Navy's interpretations. Further, some data aspects, such as current LNAPL distribution and others, cannot be well defined at present because of the sparse data network around the Red Hill tanks.

Category	Parameters
Hydrogeology	Aquifer systematics & water balance
	Aquifer parameters (T, K, S, etc.)
	Important transient conditions
	Geochemistry
LNAPL Properties	Density, viscosity, interfacial tensions
	Chemical components of NAPL
Fracture Network	Location of major fracture/bedding sets
	Orientation of fractures/bedding planes
	Fracture aperture & length ranges
	Fracture connectivity & density
Rock Matrix	Primary and secondary porosity
	Transport character of fractures
	Capillary characteristics & wettability
	Residual saturation ranges
LNAPL Distribution	Distribution in fractures
	Distribution in matrix or other features
	Density and character of distribution
	Fingering or other variable conditions
	Areal and vertical aspects of distribution

Adapted after Hardisty, 2003.

My summary interpretation of conditions in the area of the tank farm and Red Hill Ridge are as follows, based on data in available Navy reports. None of these observations appear to be included in the Navy CSM (explicitly nor implicitly), without which the CSM is both incomplete and non-conservative.

- The 2014 release likely impacted groundwater as evidenced by concentration trend increases in some wells following the release (e.g., RHMW01, RHMW02, RHMW03; attached). This is also consistent with associated sharp increases in soil vapor concentrations following the 2014 release (attached, slide deck pg. 21).
- Generally elevated and persistent dissolved-phase concentrations at RHMW02 indicate the presence of jet fuel impacts to groundwater over the full period of monitoring (i.e., jet fuel is in contact with groundwater somewhere in the vicinity).
- Periodic low-level dissolved-phase impacts at the Red Hill Shaft monitoring well suggest distal transport from the tank farm has potentially occurred, supporting the possibility of

a risk-sensitive setting (data attached). These impacts may also be related to the oily waste disposal area, but the point is that the Navy CSM does not appear to consider these data points nor their implied transport and risk potentials.

- Core samples collected beneath each Red Hill tank between 1998 - 2001 exhibit concentrations of petroleum hydrocarbons indicative of separate phase jet fuel at several tank locations and the vertical extent appears undelineated.
- Jet fuel sheens and blebs have been reported during some past monitoring events (personal comm., Robert Whittier).
- Given the above, jet fuel has likely impacted groundwater beneath the tank farm and beyond both from the 2014 and prior releases.

The Navy's current groundwater model does not reflect small-scale conditions evident in the groundwater gradients and flow patterns in the data sets presented. While the model is useful from a bulk flow perspective, its inability to characterize measured conditions suggests real-world complexities in groundwater flow remain unconsidered. These complexities are the actual hydrogeologic elements that will have a direct impact on contaminant transport. Because the model cannot at its present discretization/scale represent these conditions, any contaminant transport modeling will be of limited value. Matt Tonkin, Bob Whittier and Don Thomas all have detailed groundwater model comments and I will not delve further into this particular subject in this review.

The nonaqueous phase liquid (NAPL, a.k.a., fuels and petroleum products) aspects of the CSM similarly fail to address key technical issues of potential migration complexities. The Navy team framed its LCSM analysis in the form of a key question: *"What is the size of the largest, sudden release that would not result in unacceptable risks to groundwater receptors?"* Their preliminary answer, based on the analysis presented on January 11, 2018 was: *"Potentially over a million gallons, depending on scenario"* (GSI, January 11, 2018). *The second Navy question of chronic releases is not discussed here.*

There are several issues with the LCSM that make it non-conservative and non-representative. First, LNAPL migration in this particular environment is expected to be complex and the simplified LNAPL compartment/residualization model used by the Navy team ignores those complexities. LNAPL flow is often fingered, heterogenous, and unpredictable as shown in my February 8, 2018 slide deck (attached). The analysis by the Navy is not a dynamic release model. Rather, it is a simplified compartment model where layers of subsurface materials are assumed to residualize (absorb) LNAPL as it passes by. The method has no transient, release dependent aspects, nor does it account for any of the processes that likely make LNAPL transport a significant risk at this site. Their conclusion above is directly refuted by available site data that show the 2014 release of ~27,000 gallons impacted groundwater shortly thereafter, orders of magnitude smaller than the million gallons concluded above. Further, their model does not account for residual LNAPL already in the pore space, as evidenced by past subsurface sampling and by inference that some fraction of the 2014 release is stored as residual in the area of Tank 5. While LNAPL may be biologically degraded, not all components are amenable to those processes and regardless, time is required for mass to be depleted (transient aspects were not considered). The conservative assumption, based on field data, is that some fraction of the available residual capacity is already occupied.

At the time of the Navy's LCSM presentation, no site specific petrophysical data had been collected. We understand those data are presently being generated through core and petrophysical testing. There are

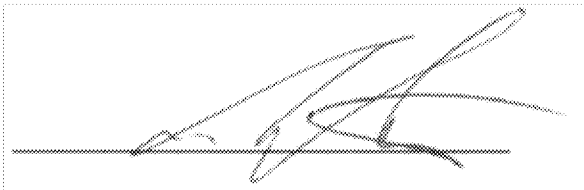
several technical reasons to suggest these data may be non-conservative. I hope to be able to work with the Navy team to consider these issues that include:

- Conditions of testing often are not reflective of release conditions and can overestimate parameters like residual saturation, which is a function of pressure and saturation history.
- Lithologic cores are a small-scale representation of a much larger system, and lab test values are often at odds with field scale test results (and often non-conservatively).
- The selection of cores and fractures needs to be considered within the context of the geologic model details, which as noted, we do not have.
- Capillary centrifuge testing methods often used by petrophysical labs have come under suspicion because those results conflict with other well-documented results.

In summary as it stands, the Navy's CSM/LCSM appears to be non-conservative and arrives at protective conclusions that are at odds with site data and conditions. While I recognize good data and work have been done by the Navy, the unavailability of that information for independent review impedes my ability to concur with various aspects of the CSM. Based on site data and work elsewhere in fractured rock settings, this particular site is more likely a high potential risk with respect to groundwater resources. There are indications of large distal transport of jet fuel components, groundwater impacts caused by a relatively small LNAPL release, and a general setting that suggests complex and rapid contaminant transport is likely. Until the Navy CSM embraces that potential, I will be unable to concur with their primary conclusions.

The opportunity to be of service is appreciated, please call if you have questions.

AQUI-VER, INC.

A handwritten signature in black ink, appearing to read 'G.D. Beckett', is written over a horizontal line. The signature is stylized with long, sweeping strokes.

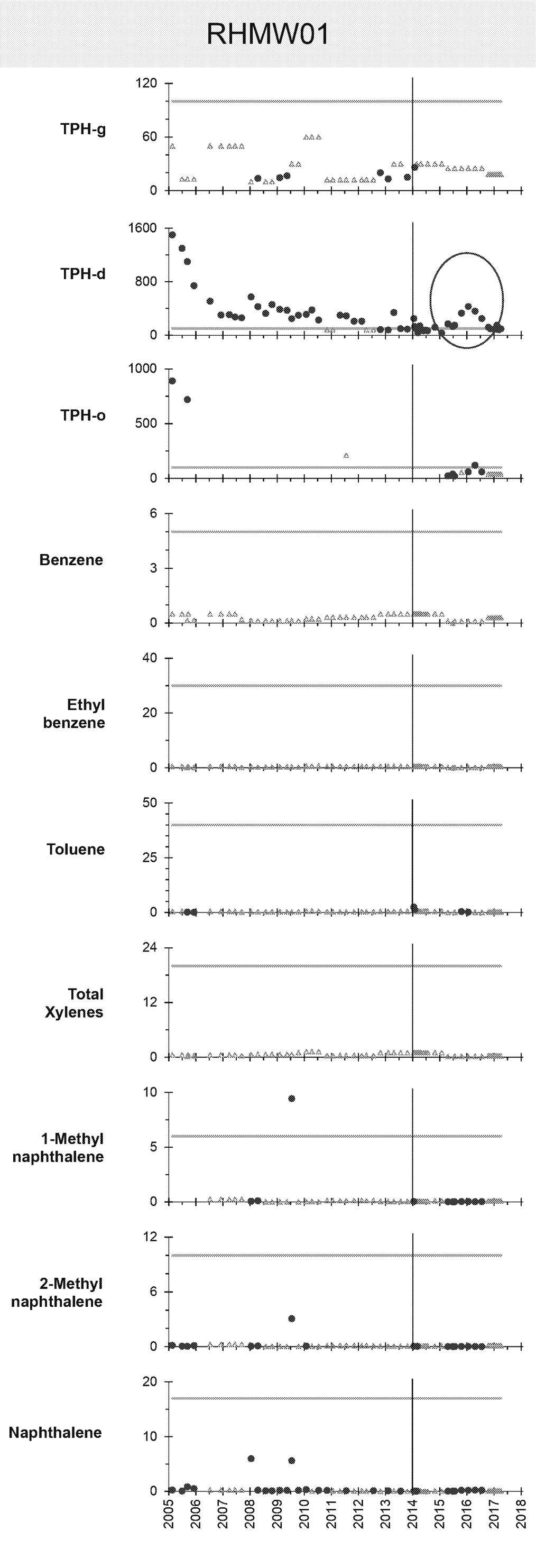
G.D. Beckett, CHg
Principal Hydrogeologist

cc: Ms. Lene K Ichinotsubo, HDOH
Mr. Bob Whittier, HDOH

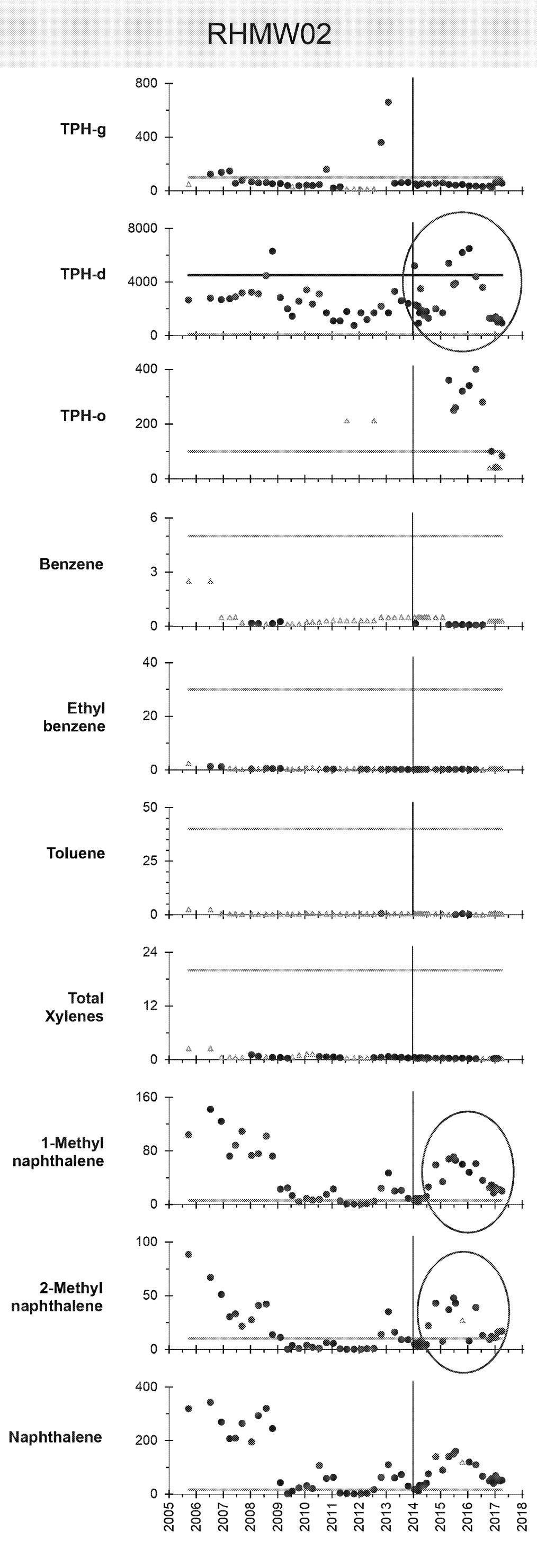
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ATTACHMENTS

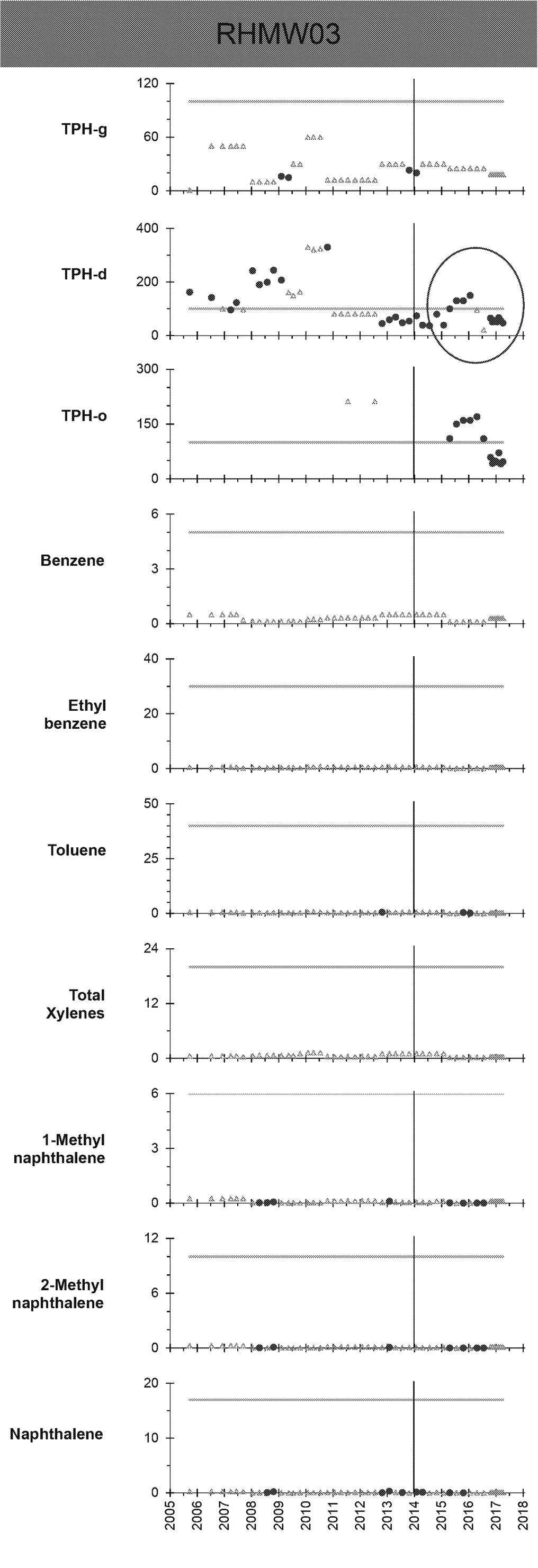
Well Concentration Trends
Analytic Data: RHMW2254-01
LNAPL Transport Slides - G.D. Beckett



All units in micrograms per liter (ug/L or parts per billion).



All units in micrograms per liter (ug/L or parts per billion).



Detections increased, scale does not allow trend observation.

All units in micrograms per liter (ug/L or parts per billion).

Appendix A.1: Cumulative Groundwater COPC Results
Second Quarter 2017 - Quarterly Groundwater Monitoring Report, Red Hill Bulk Fuel Storage Facility, JBPHH, O'ahu, Hawai'i

Method			8015							8260							8260SIM			8011			8270			8270/8270 Mod.												
Unit			TPH-d (µg/L)		TPH-g **** (µg/L)		TPH-o (µg/L)		TPH-g **** (µg/L)	1,2-Dibromoethane ***** (µg/L)		1,2-Dichloroethane ***** (µg/L)		Benzene (µg/L)		Ethylbenzene (µg/L)		Naphthalene (µg/L)		Toluene (µg/L)		Xylenes, Total (p/m-, o-xylene) (µg/L)		1,2-Dibromoethane ***** (µg/l)		1,2-Dichloroethane ***** (µg/L)		1,2-Dibromoethane ***** (µg/L)		1-Methylnaphthalene (µg/L)		2-Methylnaphthalene (µg/L)		Naphthalene (µg/L)		Phenol (µg/L)		2-(2-Methoxyethoxy)- ethanol (µg/L)
Screening Criterion			100		100		100		100	0.04		5.0		5.0		30		17		40		20		0.04		5.0		0.04		6		10		17		300		800
SSRBL			4500		—		—		—	—		—		750		—		—		—		—		—		—		—		—		—		—		—		—
Well Name	Sample ID	Sampled	Result		Result		Result		Result	Result		Result		Result		Result		Result		Result		Result		Result		Result		Result		Result		Result		Result		Result		Result
RHMW2254-01	RH-B-001	2/16/2005 ^{be}	< 50	U	< 50	U	< 100	U	—		<0.0083	U	< 0.50	U	< 0.50	U	—		1.0		< 0.50	U	—		—		—		—		< 0.020	U	< 0.020	U	—		—	
	RH-B-002	2/16/2005 ^{bf}	< 53	U	< 50	U	<110	U	—		<0.0081	U	< 0.50	U	< 0.50	U	—		1.2		< 0.50	U	—		—		—		—		< 0.022	U	< 0.022	U	—		—	
	RH-B-003	2/16/2005 ^{*bf}	< 50	U	< 50	U	< 100	U	—		<0.0082	U	< 0.50	U	< 0.50	U	—		0.81		< 0.50	U	—		—		—		—		< 0.021	U	< 0.021	U	—		—	
	RH-B-004	6/28/2005 ^{ae}	43	J	< 13	U	—		—		< 0.00096	U	<0.50 ^b	U	<0.50 ^b	U	—		<0.50 ^b	U	<0.50 ^b	U	—		—		—		—		<0.020 ^b	U	<0.020 ^b	U	—		—	
	RH-B-005	6/28/2005 ^{*ae}	67	Z	< 13	U	—		—		< 0.00096	U	<0.50 ^b	U	<0.50 ^b	U	—		<0.50 ^b	U	<0.50 ^b	U	—		—		—		—		<0.020 ^b	U	<0.020 ^b	U	—		—	
	RH-B-006	6/28/2005 ^{*af}	58	Z	< 13	U	—		—		< 0.00096	U	<0.50 ^b	U	<0.50 ^b	U	—		<0.50 ^b	U	<0.50 ^b	U	—		—		—		—		<0.021 ^b	U	<0.021 ^b	U	—		—	
	RH-B-007	9/8/2005 ^{ae}	45	J	< 13	U	59	J	—		< 0.00096	U	< 0.12	U	< 0.14	U	—		< 0.11	U	< 0.22	U	—		—		—		—		<0.020 ^b	U	0.085		—		—	
	RH-B-008	9/8/2005 ^{af}	< 50	U	< 13	U	<28	U	—		< 0.00096	U	< 0.12	U	< 0.14	U	—		< 0.11	U	< 0.22	U	—		—		—		—		<0.020 ^b	U	<0.020 ^b	U	—		—	
	RH-B-009	9/8/2005 ^{*af}	<50 ^d	U	< 13	U	<100 ^d	U	—		< 0.00096	U	< 0.12	U	< 0.14	U	—		< 0.11	U	< 0.22	U	—		—		—		—		<0.020 ^b	U	0.045		—		—	
	RHMW2254W01	9/20/2005 ^{bd}	—		—		—		—		< 0.50	U	< 0.50	U	< 0.50	U	< 0.50	U	< 1.0	U	< 0.50	U	< 0.50	U	—		—		—		—		—		—		—	
	RH-B-010	12/6/2005 ^{ae}	38	J	< 13	U	—		—		<0.0096 ^b	U	< 0.12	U	< 0.14	U	—		< 0.11	U	< 0.22	U	—		—		—		—		0.038		0.036		—		—	
	RH-B-011	12/6/2005 ^{*ae}	24	J	< 13	U	—		—		<0.0094 ^b	U	< 0.12	U	< 0.14	U	—		< 0.11	U	< 0.22	U	—		—		—		—		0.022		0.024		—		—	
	RH-B-012	12/7/2005 ^{af}	< 20	U	< 13	U	—		—		<0.0095 ^b	U	< 0.12	U	< 0.14	U	—		< 0.11	U	< 0.22	U	—		—		—		—		0.0071	J	0.011	J	—		—	
	RHMW2254-01-GW02	7/10/2006 ^{ad}	< 110	U	< 50	U	—		—		< 0.50	U	< 0.50	U	< 0.50	U	< 0.50	U	< 1.0	U	< 0.50	U	< 0.50	U	—		—		< 0.26	U	< 0.26	U	< 0.26	U	—		—	
	RHMW2254-01-GW06	12/5/2006 ^{ad}	< 100	U	< 50	U	—		—		< 0.50	U	< 0.50	U	< 0.50	U	< 0.50	U	< 1.0	U	< 0.50	U	< 0.50	U	—		—		< 0.25	U	< 0.25	U	< 0.25	U	—		—	
	RHMW2254-01-WG07	3/27/2007 ^a	< 98	U	< 50	U	—		—		< 0.50	U	< 0.50	U	< 0.50	U	< 0.50	U	< 1.0	U	< 0.50	U	< 0.50	U	—		—		< 0.24	U	< 0.24	U	< 0.24	U	—		—	
	RHMW2254-01-WG08	6/12/2007 ^a	< 98	U	< 50	U	—		—		< 0.50	U	< 0.50	U	< 0.50	U	< 0.50	U	< 1.0	U	< 0.50	U	< 0.50	U	—		—		< 0.25	U	< 0.25	U	< 0.25	U	—		—	
	RHMW2254-01-WG0	9/10/2007 ^a	< 97	U	< 50	U	—		—		< 0.20	U	< 0.20	U	< 0.20	U	< 0.20	U	< 0.44	U	< 0.27	U	< 0.36	U	—		—		< 0.25	U	< 0.25	U	< 0.25	U	—		—	
	RHMW2254-01-WG10	1/15/2008 ^a	< 102	U	< 10.0	U	—		—		< 0.310	U	< 0.150	U	< 0.120	U	< 0.310	U	< 0.620	U	< 0.310	U	< 0.620	U	—		—		< 0.0150	U	< 0.0150	U	< 0.0310	U	—		—	
	RHMW2254-01-WG10.1	2/6/2008 ^a	< 100	U	—		—		—		—		—		—		—		—		—		—		—		—		—		—		—		—		—	
	RHMW2254-01-WG10.1	2/6/2008 ^a	< 10.3	U	—		—		—		—		—		—		—		—		—		—		—		—		—		—		—		—		—	
	RHMW2254-01-WG11	4/15/2008 ^a	< 86.0	U	< 10.0	U	—		—		< 0.310	U	< 0.150	U	< 0.120	U	< 0.310	U	< 0.620	U	< 0.310	U	< 0.620	U	—		—		0.0435	J	0.0561		< 0.0332	U	—		—	
	RHMW2254-01-WG12	7/29/2008 ^a	< 83.3	U	< 10.0	U	—		—		< 0.310	U	< 0.150	U	< 0.120	U	< 0.310	U	< 0.620	U	< 0.310	U	< 0.620	U	—		—		< 0.0156	U	< 0.0156	U</						

Appendix A.1: Cumulative Groundwater COPC Results (cont'd)
Second Quarter 2017 - Quarterly Groundwater Monitoring Report, Red Hill Bulk Fuel Storage Facility, JBP HH, O'ahu, Hawai'i

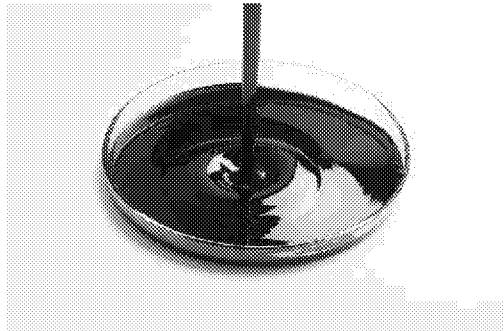
Method			8015						8260						8260SIM			8011	8270			8270/8270 Mod.														
Unit			TPH-d	TPH-g ****		TPH-o	TPH-g ****		1,2-Dibromoethane ****		1,2-Dichloroethane ****		Benzene		Ethylbenzene	Naphthalene		Toluene	Xylenes, Total (p/m-, o-xylene)	1,2-Dibromoethane ****	1,2-Dichloroethane ****	1,2-Dibromoethane ****	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Phenol	2-(2-Methoxyethoxy)- ethanol									
Screening Criterion			100	100		100	100		0.04		5.0		5.0		30	17		40	20	0.04	5.0	0.04	6	10	17	300	800									
SSRBL			4500	—		—	—		—		—		750		—	—		—	—	—	—	—	—	—	—	—	—									
Well Name	Sample ID	Sampled	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result									
RHMW2254-01 (cont'd)	ES094	5/28/2014	< 12	U	—	—	—	—	—	—	—	< 0.50	U	< 0.50	U	—	—	< 0.50	U	< 1.0	U	—	—	—	< 0.050	U	< 0.050	U	< 0.050	U	—	—				
	ES102	6/24/2014	< 12	U	—	—	—	—	—	—	—	< 0.50	U	< 0.50	U	—	—	< 0.50	U	< 1.0	U	—	—	—	< 0.049	U	< 0.049	U	< 0.049	U	—	—				
	ES107	7/22/2014	< 12	U	—	—	—	< 30	U	< 0.50	U	< 0.50	U	< 0.50	U	—	—	< 0.50	U	< 1.0	U	—	—	—	< 0.048	U	< 0.048	U	< 0.048	U	—	—				
	ES117	10/28/2014	22	J,HD	—	—	—	< 30	U	< 0.50	U	< 0.50	U	< 0.50	U	—	—	< 0.50	U	< 1.0	U	—	—	—	< 0.097	U	< 0.049	U	< 0.049	U	—	—				
	ES125	1/27/2015	< 12	U	—	—	—	< 30	U	< 0.50	U	< 0.50	U	< 0.50	U	—	—	< 0.50	U	< 1.0	U	—	—	—	< 0.10	U	< 0.050	U	< 0.050	U	—	—				
	ES134	4/21/2015	14	BJ	< 25	U	37	BJ	—	< 0.20	U	—	—	< 0.10	U	< 0.10	U	—	< 0.10	U	< 0.20	U	< 0.010	U	< 0.015	U	< 0.0040	U	< 0.0050	UJ	< 0.0050	UJ	< 0.0050	UJ	—	—
	ES149	7/21/2015	17	J	< 25	U	42	J	—	< 0.20	U	—	—	< 0.10	U	< 0.10	U	—	< 0.10	U	< 0.20	U	—	< 0.015	U	< 0.0040	U	< 0.0050	U	< 0.0050	U	< 0.0050	U	—	—	
	ERH009	10/20/2015	16	BJ	< 25	U	< 53	UB	—	< 0.20	U**	—	—	< 0.10	U**	< 0.10	U**	—	0.990	Tb**	< 0.20	U**	—	< 0.015	U	< 0.0040	U	< 0.0050	U	< 0.0050	UB	< 0.0050	UB	—	—	
	ERH021	1/20/2016	21	BJ	< 25	U	< 54	UB	—	< 0.20	U	—	—	< 0.10	U	< 0.10	U	—	0.16	TbJ	< 0.20	U	—	< 0.015	U	< 0.0040	U	< 0.0050	U	< 0.0050	U	< 0.0050	U	—	—	
	ERH037	4/20/2016	< 21	UB	< 25	U	< 61	UB	—	—	—	—	—	< 0.10	U	0.10	J	—	< 0.10	U	< 0.20	U	—	—	—	< 0.0050	U	< 0.0050	U	< 0.0050	U	—	—	—		
	ERH051	7/20/2016	< 21	U	< 25	U	< 52	UBF	—	—	—	—	—	< 0.10	U	< 0.10	U	—	< 0.10	U	< 0.20	U	—	—	—	< 0.0050	U	< 0.0050	U	< 0.0050	UBF	—	—	—		
	ERH088/092	10/18/2016*	< 25	U	—	< 40	U	< 18	UJ	—	—	—	—	< 0.30	U	< 0.50	U	—	< 0.30	U	< 0.30	U	—	—	—	< 0.10	U	< 0.10	U	< 0.10	U	< 4.00	U	< 80.0	UJ	
	ERH115/116	11/14/2016*	< 25	U	—	< 40	U	< 18	U	—	—	—	—	< 0.30	U	< 0.50	U	—	< 0.30	U	< 0.30	U	—	—	—	< 0.10	U	< 0.10	U	< 0.10	U	< 4.00	U	< 80.0	U	
	ERH135/137	12/12/2016*	14	J	—	16	J	< 18	U	—	—	—	—	< 0.30	U	< 0.50	U	—	< 0.30	U	< 0.30	U	—	—	—	< 0.10	U	< 0.10	U	< 0.10	U	< 4.00	U	< 80.0	U	
	ERH161/162	1/10/2017*	< 25	U	—	< 40	U	< 18	U	—	—	—	—	< 0.30	U	< 0.50	U	—	< 0.30	U	< 0.30	U	—	—	—	< 0.10	U	< 0.10	U	< 0.10	U	< 4.00	U	< 80.0	U	
ERH205/206	2/7/2017*	< 25	U	—	< 40	U	< 18	U	—	—	—	—	< 0.30	U	< 0.50	U	—	< 0.30	U	< 0.30	U	—	—	—	< 0.10	U	< 0.10	U	< 0.10	U	< 4.00	U	< 80.0	U		
ERH257/258	3/6/2017	< 25	U	—	< 40	U	< 18	U	—	—	—	—	< 0.30	U	< 0.50	U	—	< 0.30	U	< 0.30	U	—	—	—	< 0.10	U	< 0.10	U	< 0.10	U	< 4.00	U	< 80.0	U		
ERH292/293	4/3/2017	< 25	U	—	< 40	U	< 18	U	—	—	—	—	< 0.30	U	< 0.50	U	—	< 0.30	U	< 0.30	U	—	—	—	< 0.10	U	< 0.10	U	< 0.10	U	< 4.00	U	< 80.0	U		

Considerations on LNAPL Transport at the Navy Red Hill Facility

Presented to:
Hawai'i Department of Health, EPA & Interested Parties

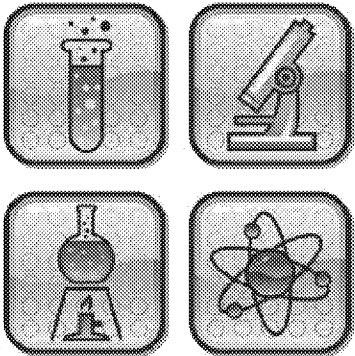
February 8, 2018
G.D. Beckett, PG, CHG
AQUI-VER, INC.

Topics



- Overview of preliminary Navy LCSM
- LNAPL migration complexities
 - Particularly in this type of setting
 - Apparent absence of key site parameters
- Indications provided by site data
 - Potential LNAPL impact to g.w.
 - Potential directions of migration
- Implications
- *We cannot know/describe everything*
 - *But we can evaluate important aspects*
 - *Conservatively infer or measure*

Some General Observations by Others



- Pore scale processes are important
 - But won't be seen at macro-scale
 - Homogenization can yield insights, but limited
- Heterogeneity **cannot** be modeled deterministically
 - Micro-scale phenomena appear semi-random
 - Stochastic approaches should be considered
 - *Abbreviated from Russell et al., NSF (2008)*
- Small volumes of LNAPL in ~vertical fractures can produce significant LNAPL heads:
 - Significant depth of penetration into aquifer possible
 - Monitoring well observations are not straightforward
- The presence of potentially mobile LNAPL beneath historical groundwater surface lows should be considered
 - *Abbreviated from Hardisty et al., J. of Eng. Geo & Hydro 2003*

JANUARY 2014 RELEASE

SPECIFIC RETENTION ANALYSIS

120

Apply three different volume scenarios holding spilled LNAPL:

Scenario A (Least Conservative):

13 cubic feet basalt needed to hold one gallon LNAPL

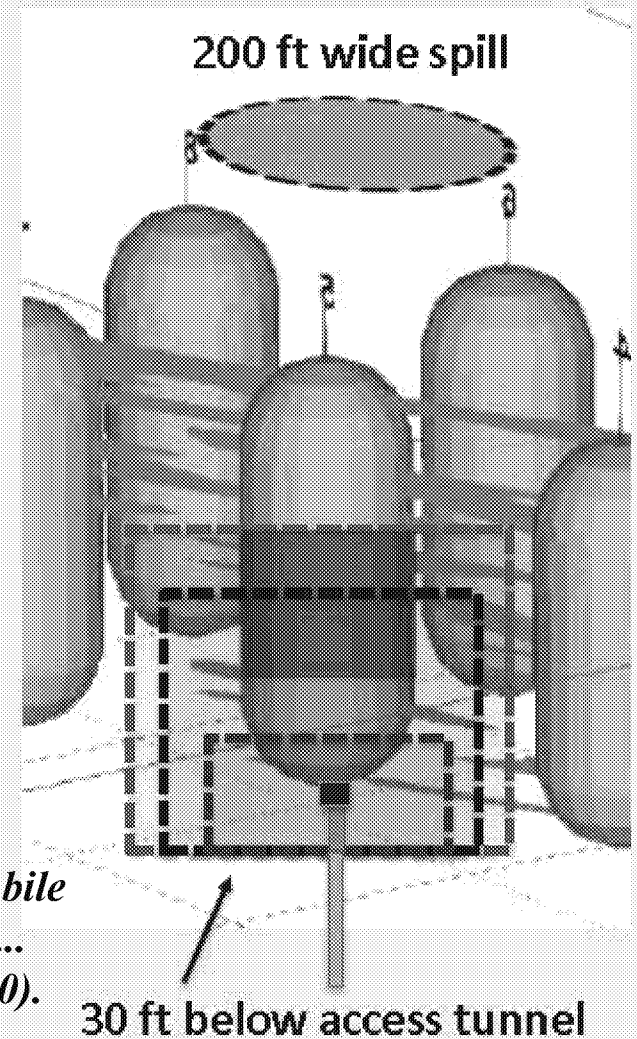
Scenario B: (Most Likely)

20 cubic feet basalt needed to hold one gallon LNAPL

Scenario C: (Most Conservative)

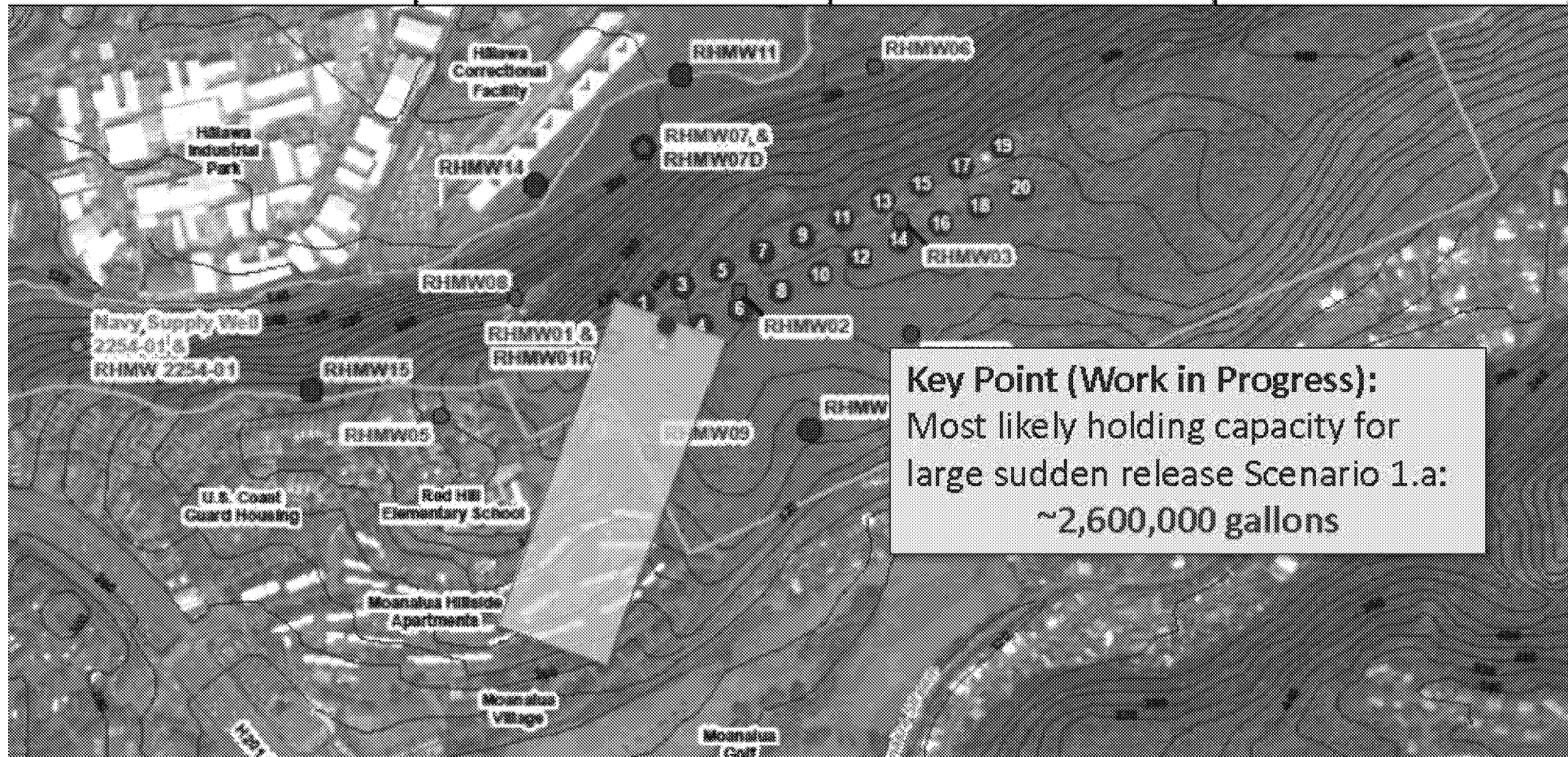
53 cubic feet basalt needed to hold one gallon LNAPL

Use of residual NAPL concentration in soil values for screening immobile (retained) NAPL presumes homogenous soils.. Macropores, fractures ... must be recognized in applications. (paraphrased from API Bul 9, 2000).

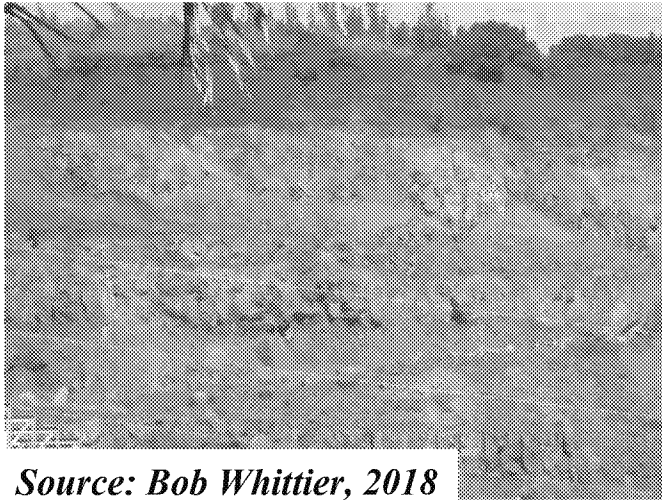


HYPOTHETICAL LARGE SUDDEN RELEASE HOLDING CAPACITY RESULTS FOR SCENARIO 1

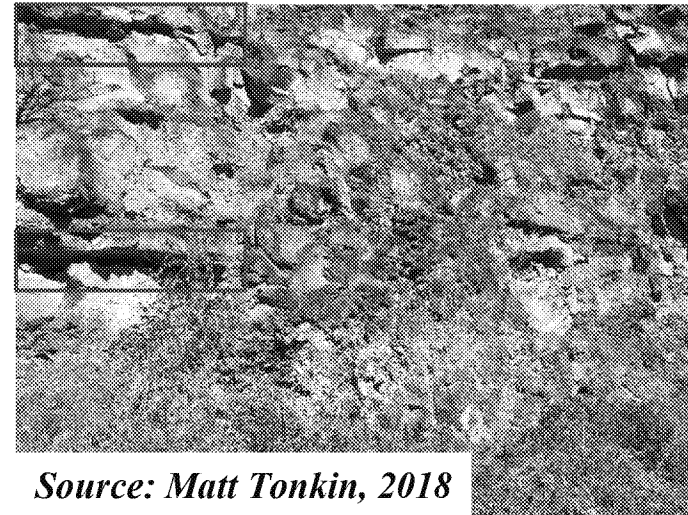
Hypothetical LNAPL Release Scenario	This is the Maximum Release Volume That Will:	Mostly Likely LNAPL Holding Capacity (gallons)	10 th to 90 th Percentile Range (gallons)
Scenario 1a (Low Release)	Protect users of groundwater in the vicinity of the Facility	2,600,000	1,900,000 - 3,600,000



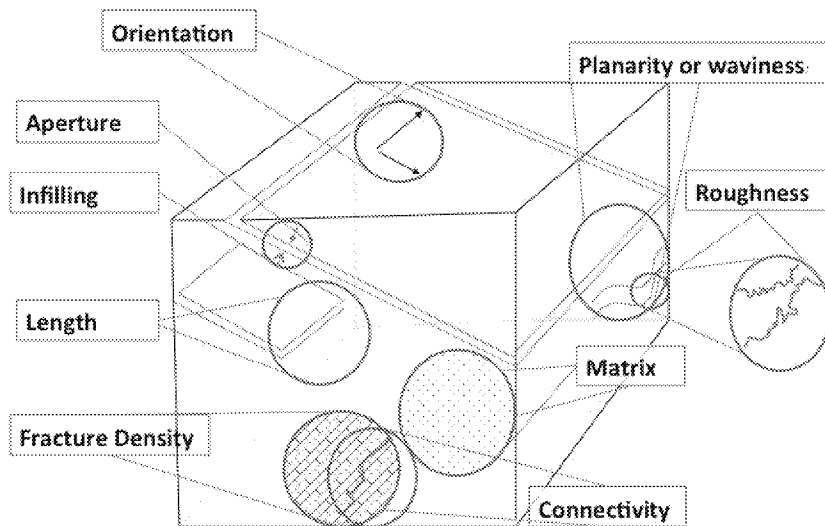
Factors Affecting Flow Heterogeneity



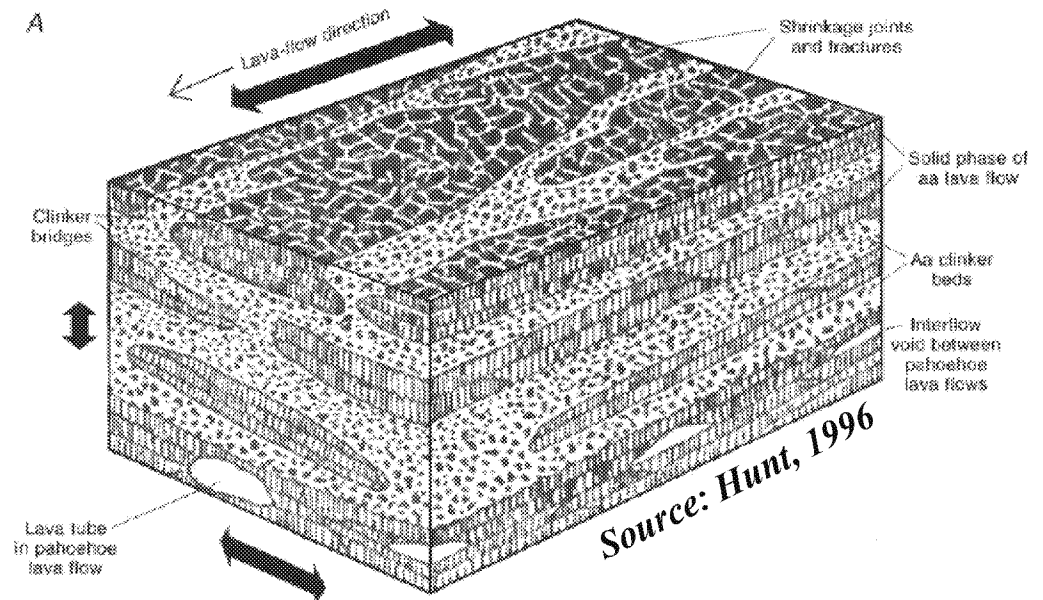
Source: Bob Whittier, 2018



Source: Matt Tonkin, 2018



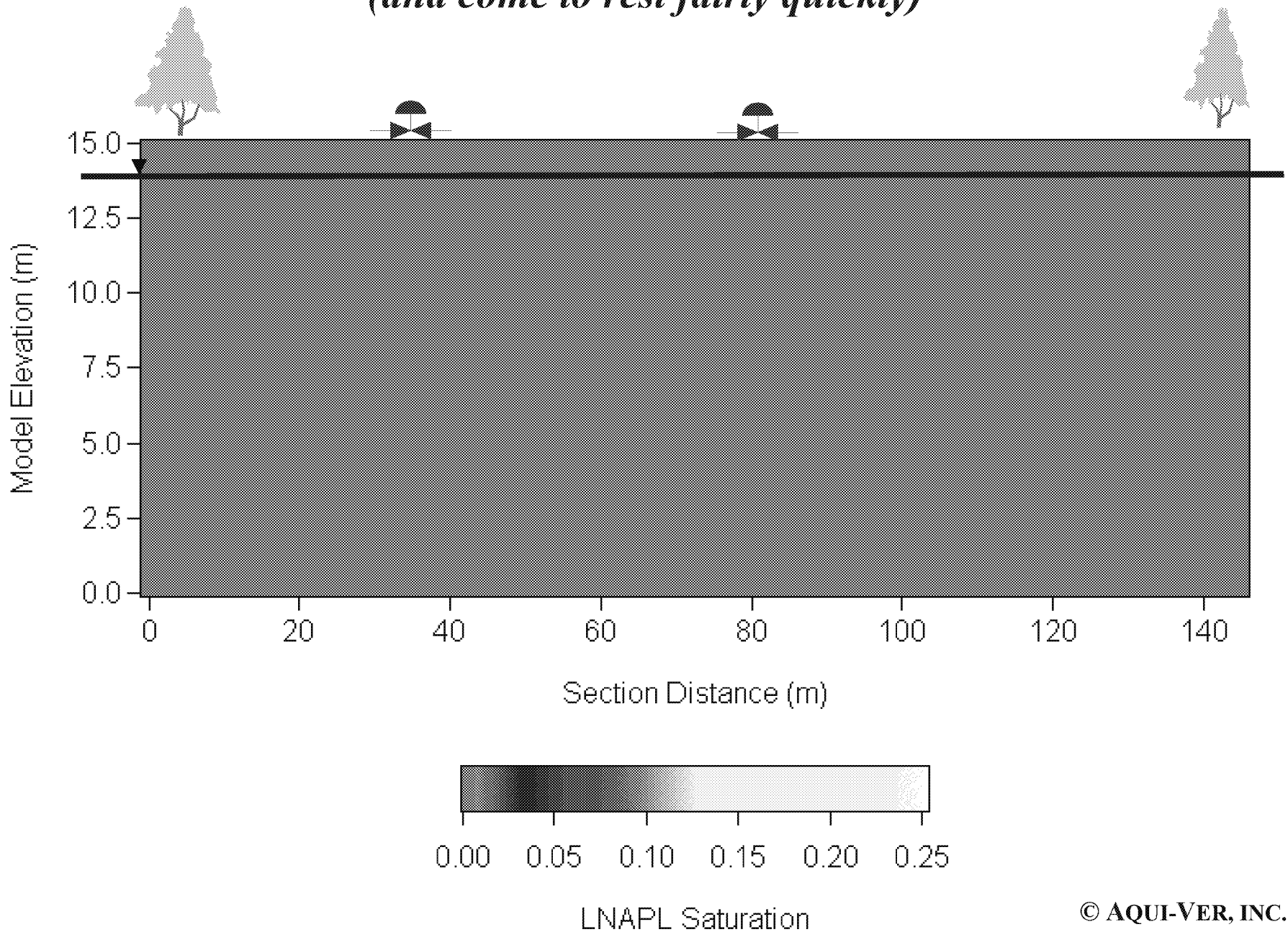
Source: ITRC, 2017



Source: Hunt, 1996

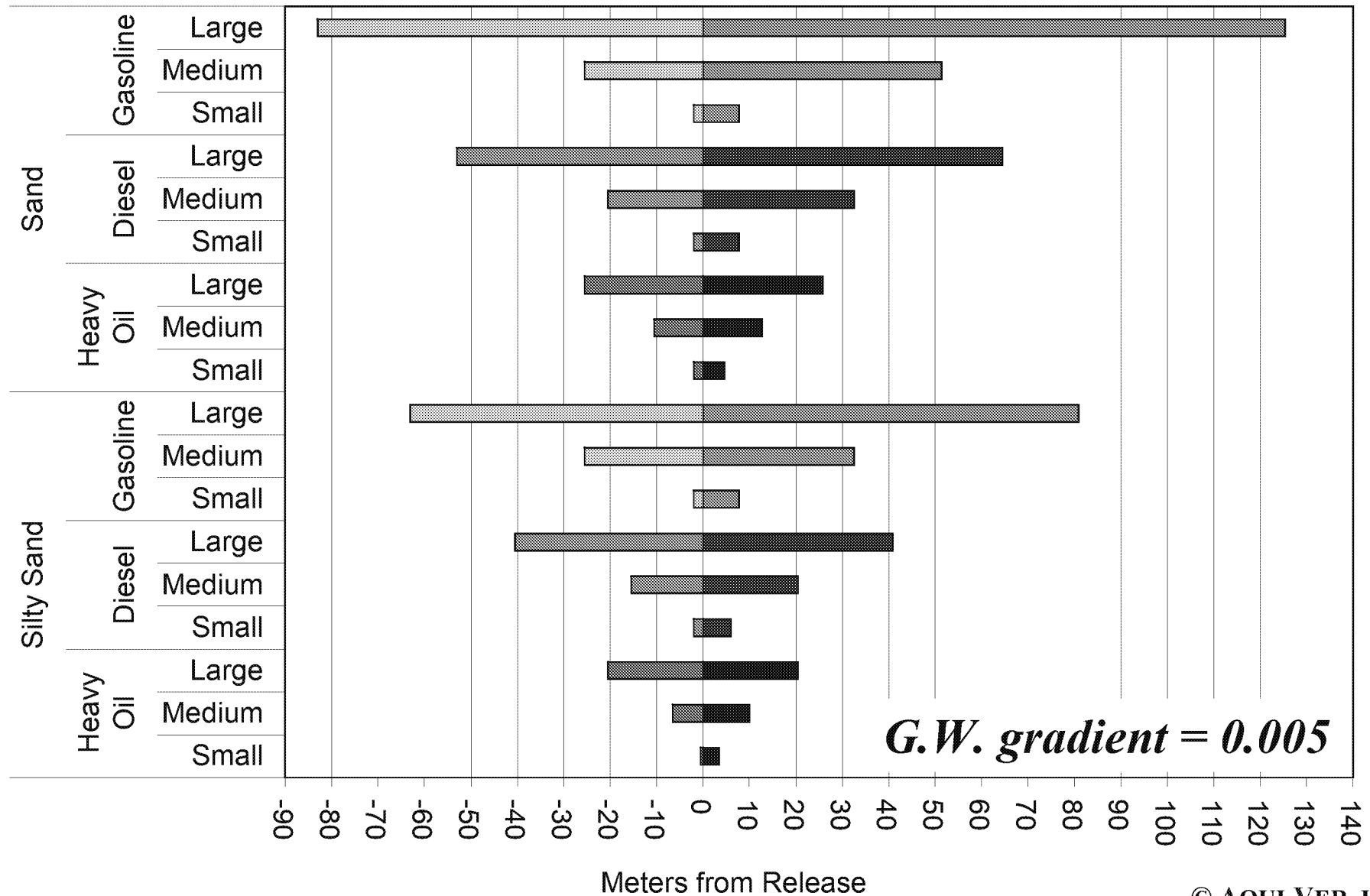
LNAPL Release Are Highly Transient

(and come to rest fairly quickly)



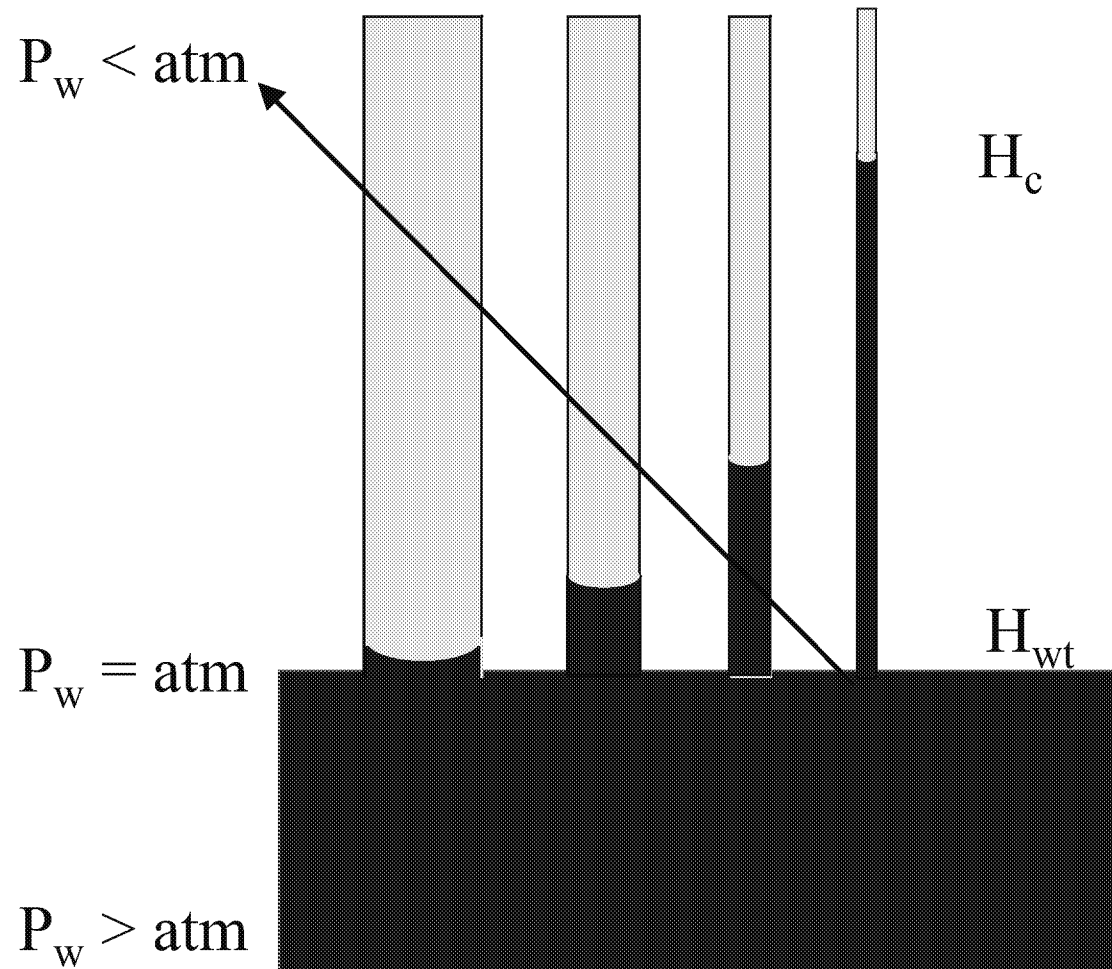
Comparative Lateral LNAPL Migration

(converse is true for vertical migration)



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Importance of Capillarity - Wettability



*As pore or aperture size gets smaller,
capillary rise gets bigger. Harder for NAPL to enter small
pores, requires greater pressure.*

Wetting Phase Importance

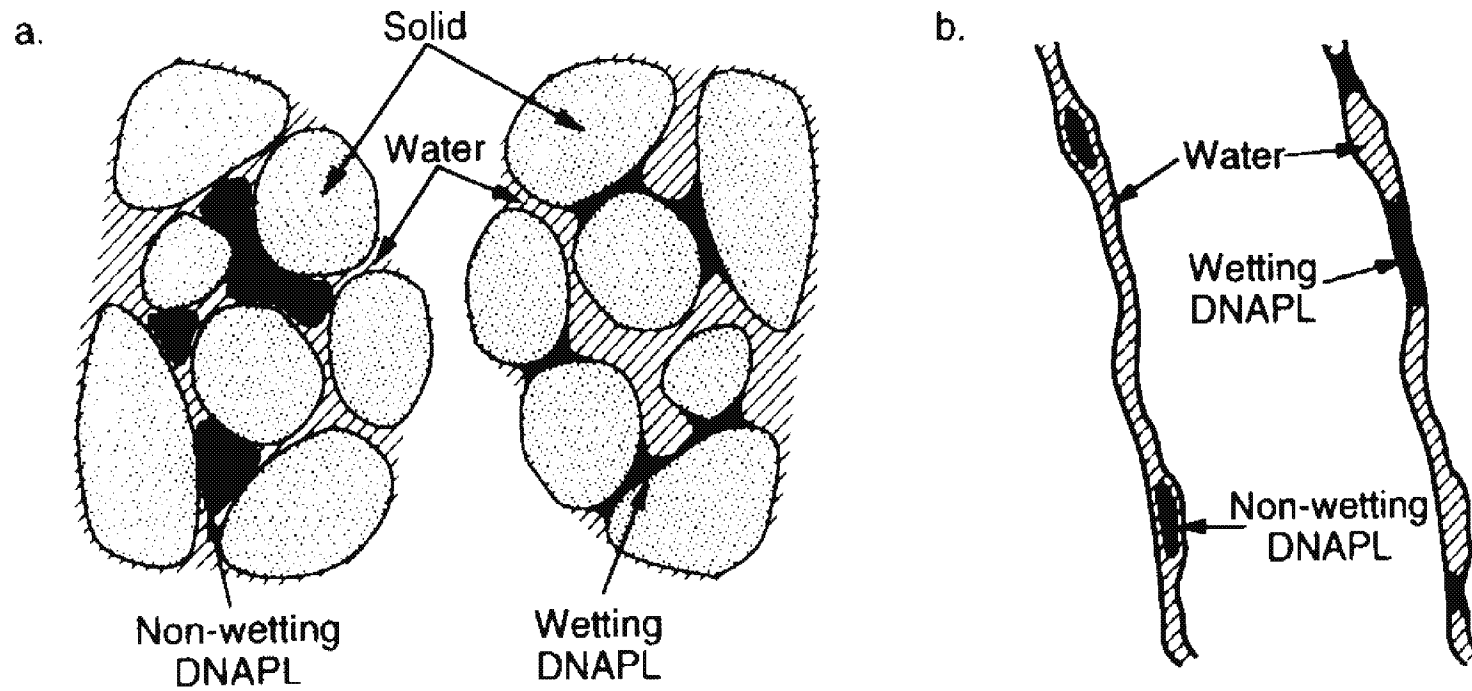


Figure 2.3 Pore-scale representation of non-wetting and wetting DNAPL residual in: a) water-saturated sand; and b) a fracture.

after Pankow & Cherry, 1996

Initial vs. Residual Saturation Relationship (for these specific study soils & oils)

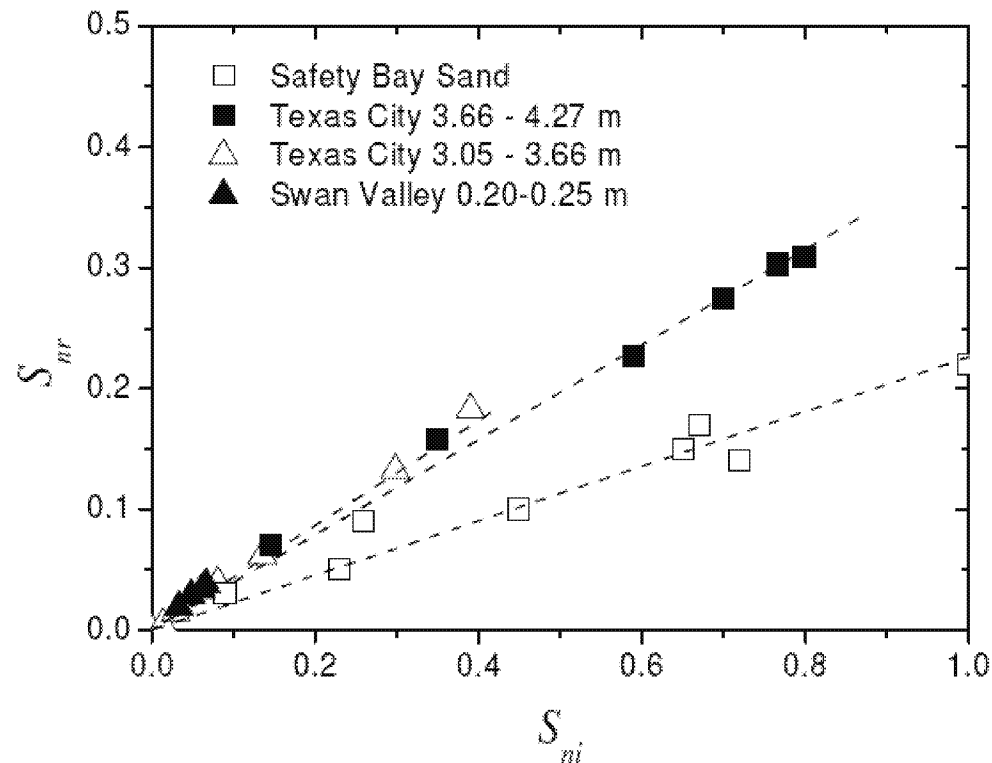
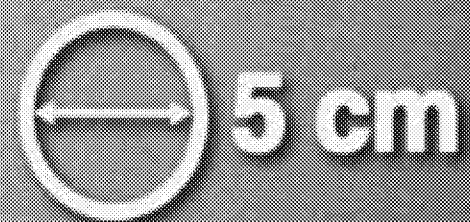
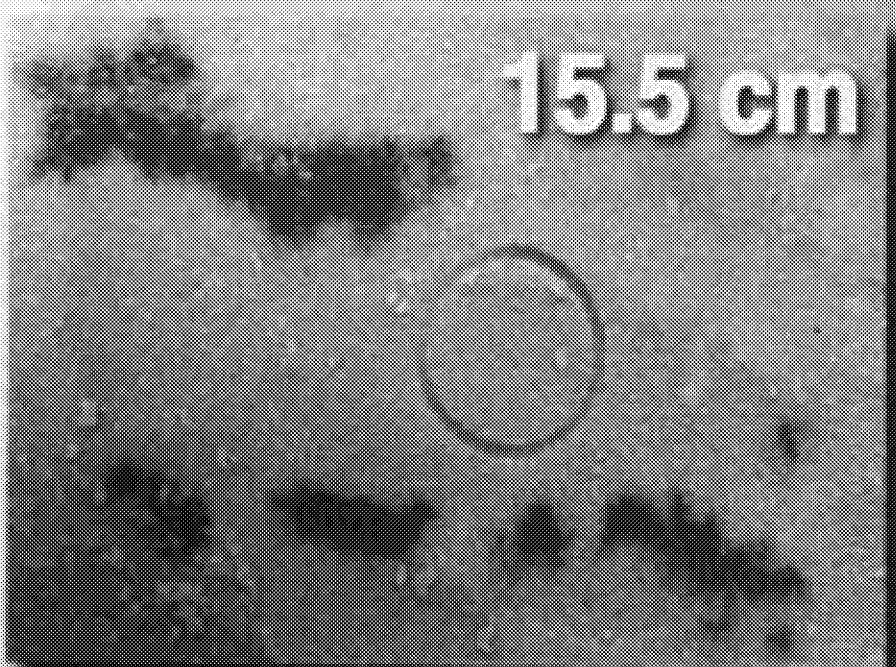
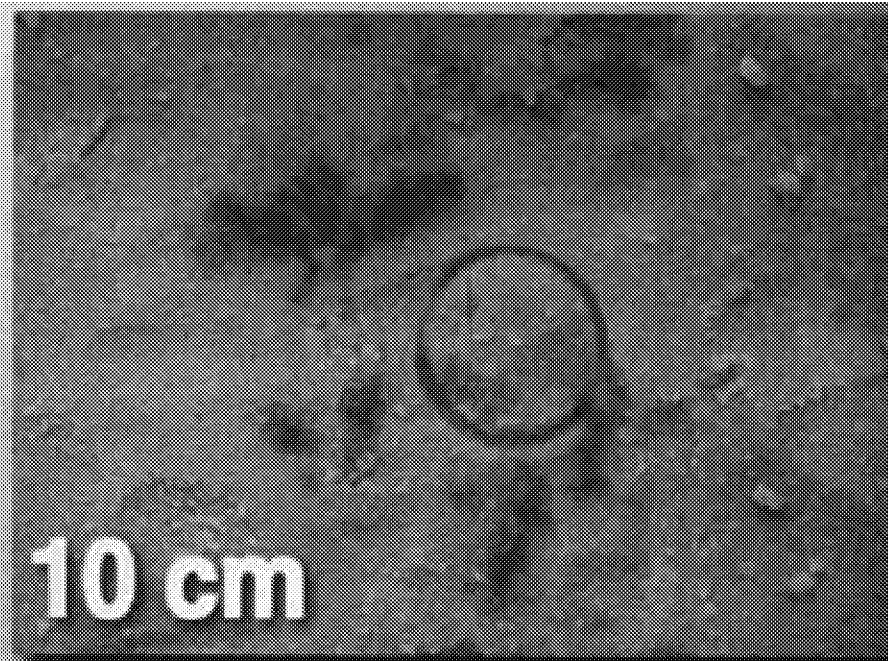
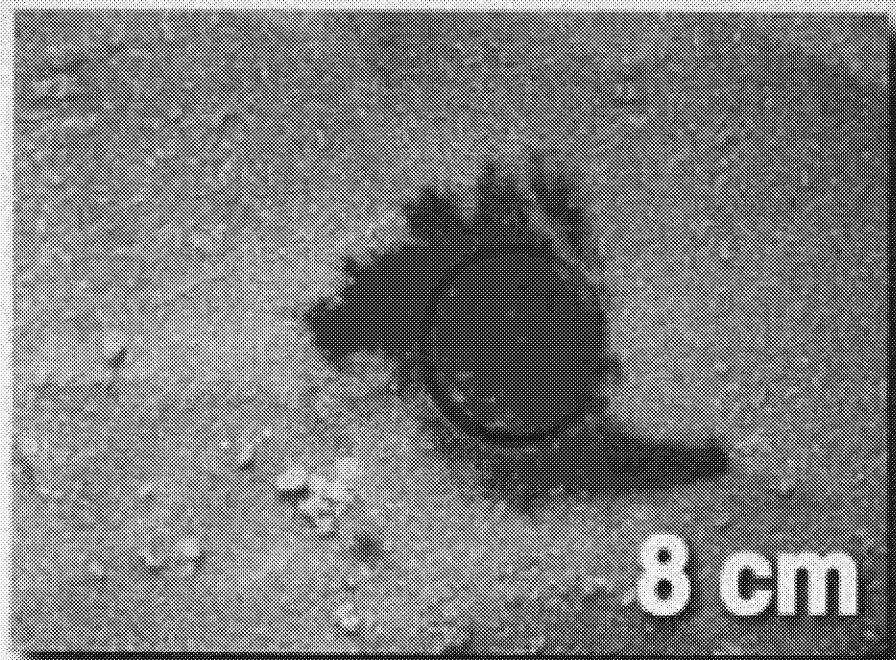


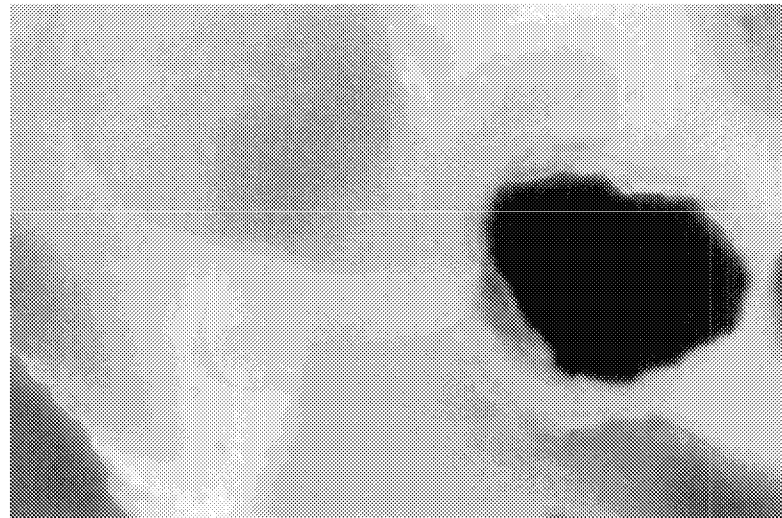
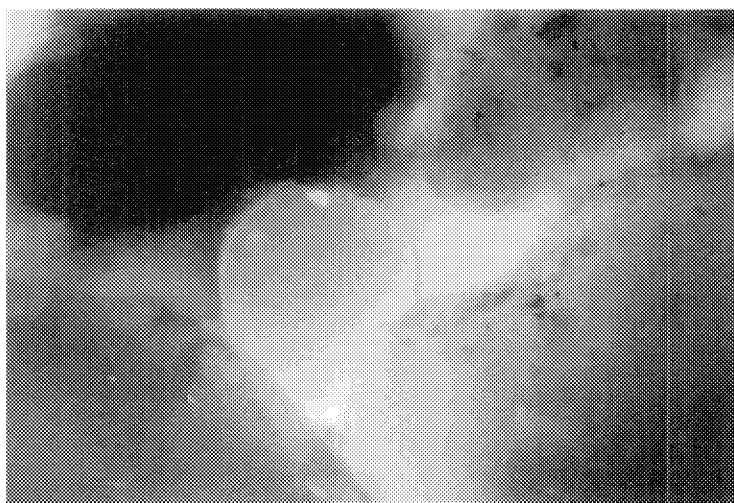
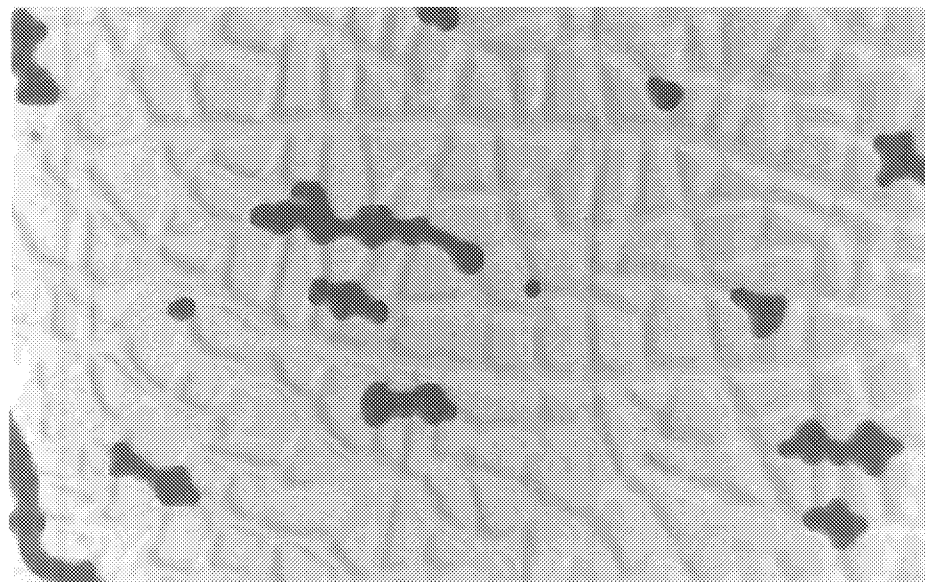
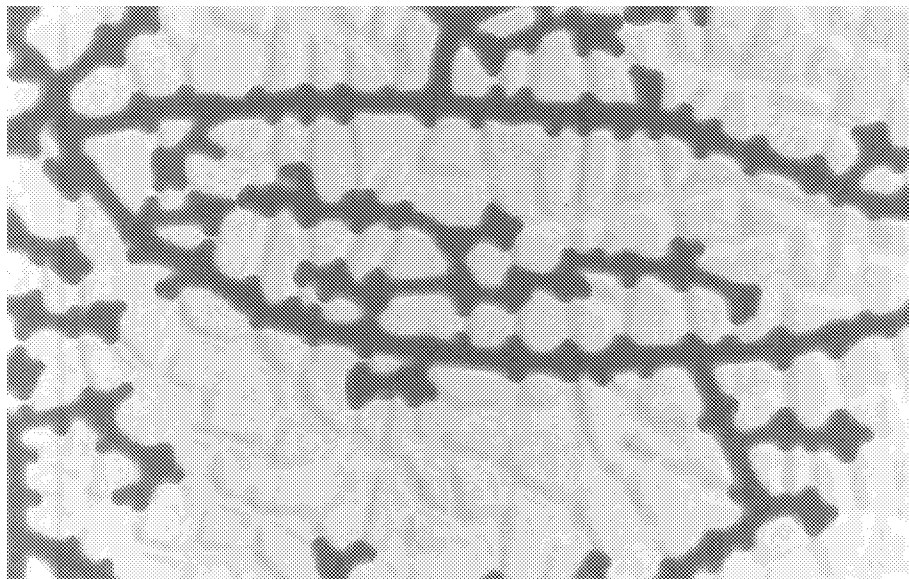
Fig. 4. Residual NAPL saturation, S_{nr} , as a function of initial NAPL saturation, S_{ni} , for the samples of the present study and for the Safety Bay Sand of Steffy *et al.* 1997. Symbols show measured values and lines show the fitted linear regression $S_{nr} = bS_{ni}$.

(From Johnston, C., & Adamski, M., 2005)



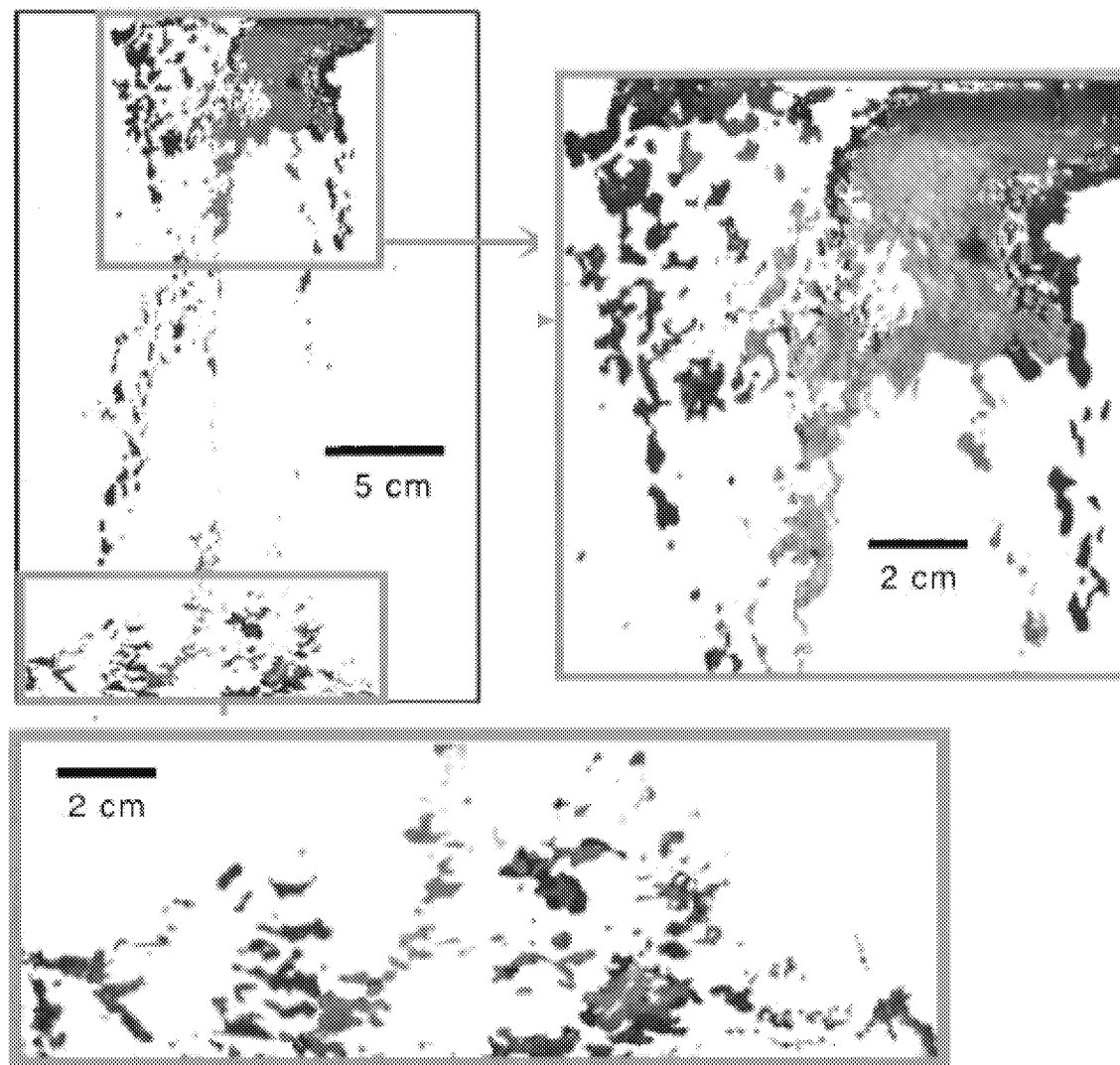
**Johnson 1987
edited by Feenstra 1993**

Oil Displacing Water & Residual Oil



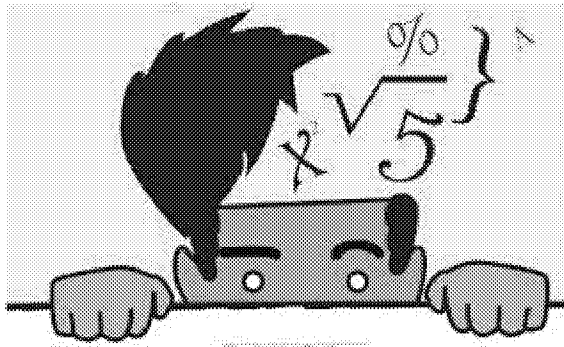
(Source: Wilson et al., 1990; EPA 600/6-90/004)

NAPL Distribution in a Fracture

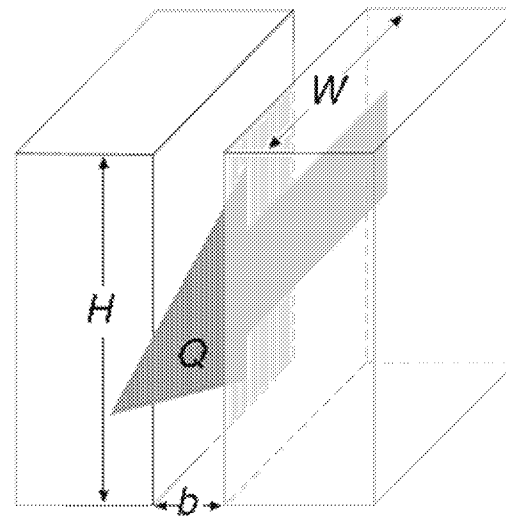


Geller et al., 2000

Just a Little Math... Cubic & Quintic Flow



For “simple” fractures



$$Q = -\frac{\rho g}{12\mu} b^3 \partial h$$

$$K = \frac{2b^2 \rho g}{12\mu}$$

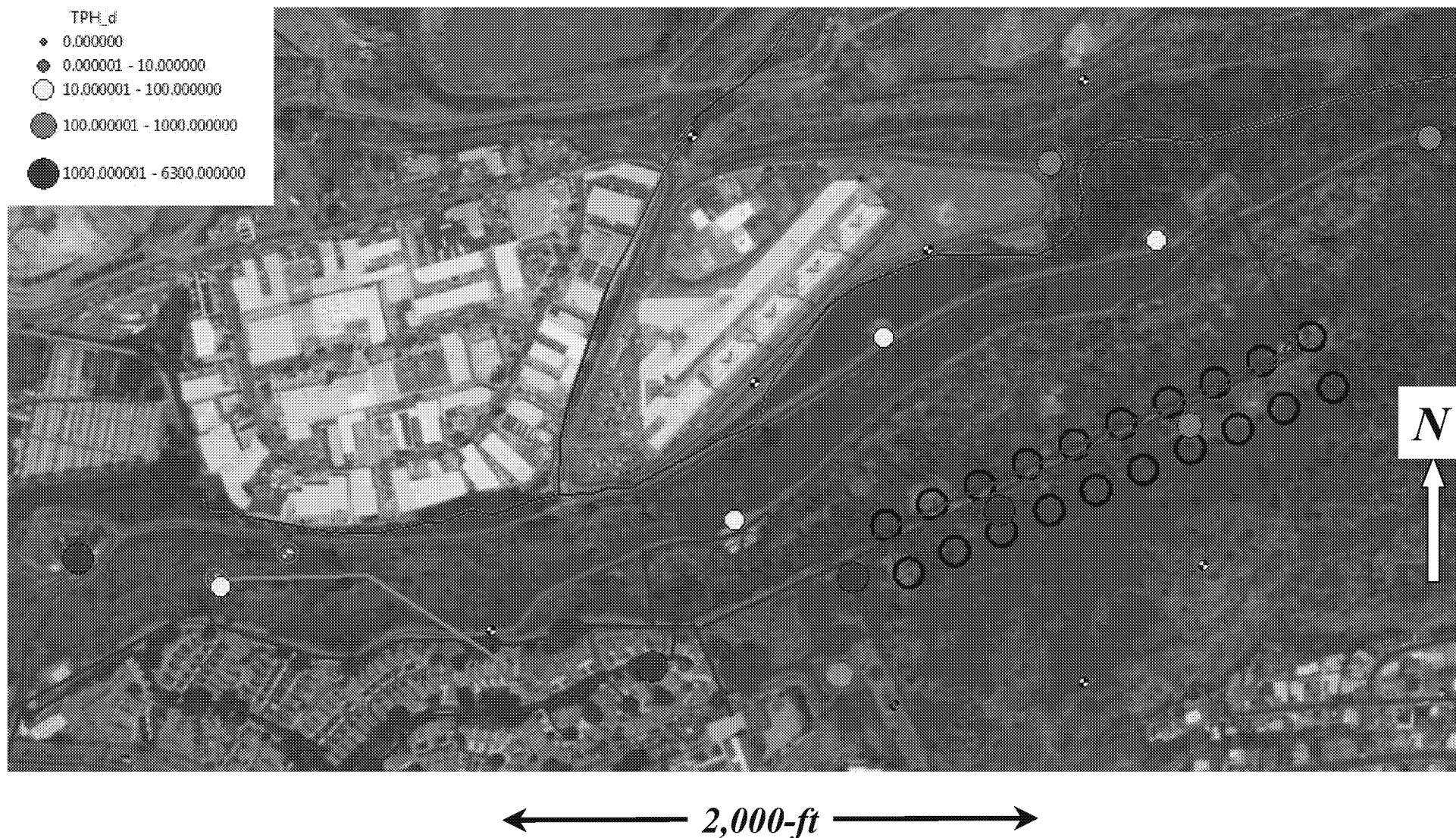
Holy exponential cow!

*Suggested for “real” fractures with
aperture/length correlations*

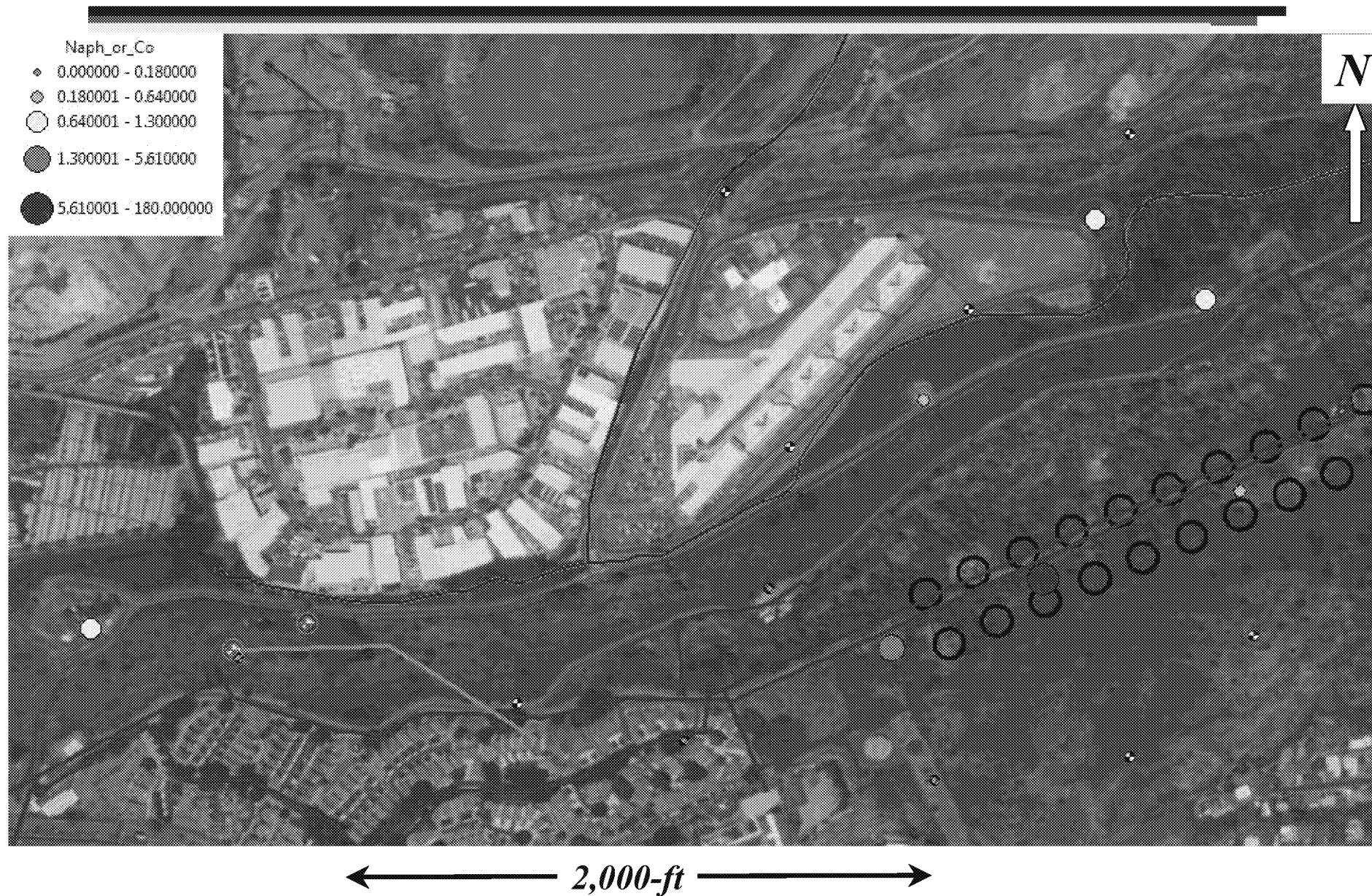
$$Q = -\frac{4\rho g}{3\mu(\pi\alpha)^2} b^5 \partial h$$

after Climczak et al., 2009

TPH_d Maximums in Groundwater



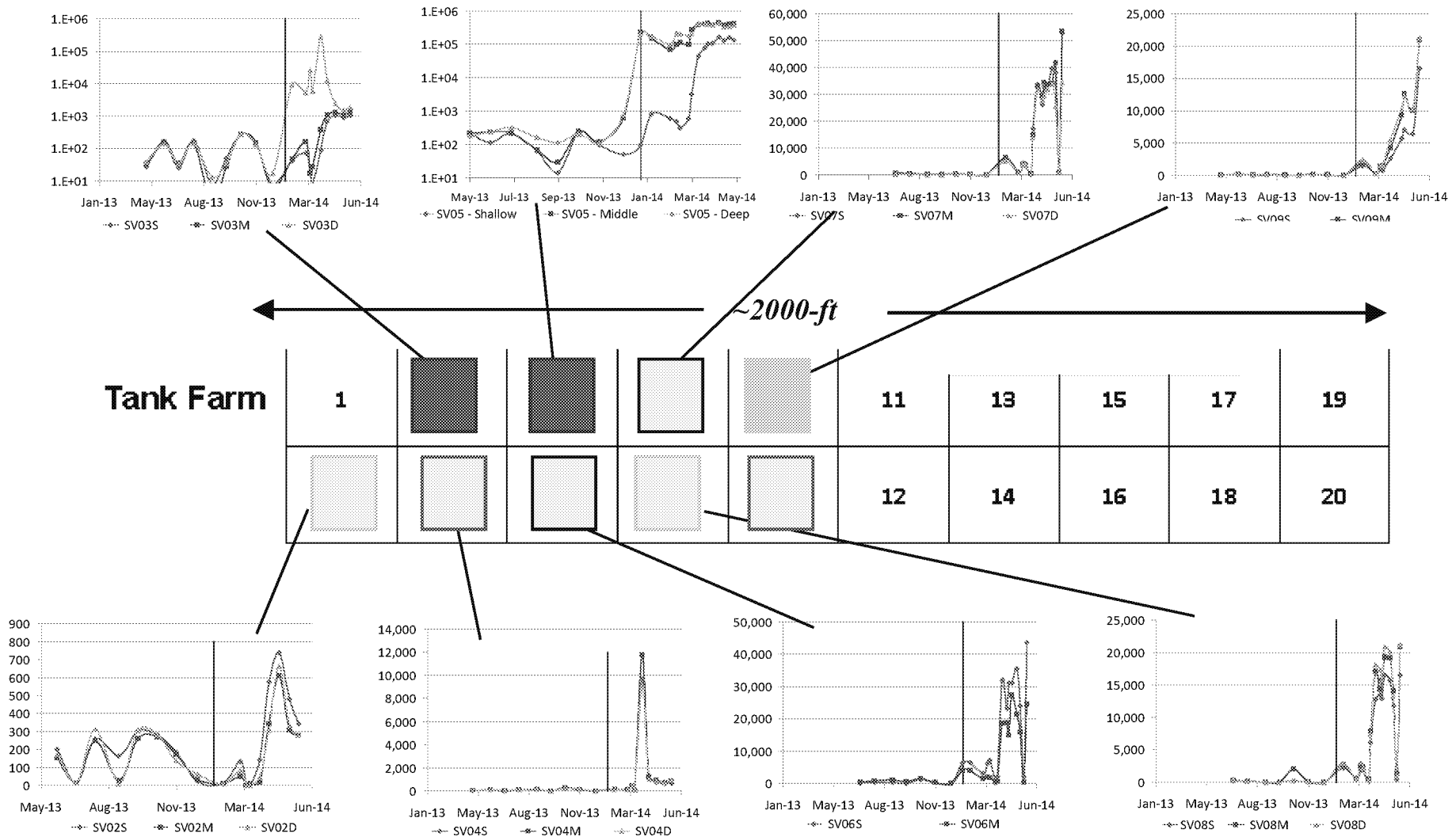
Naphthalene/CoC Maximums in Groundwater



Boring Samples; TPH > 1,000 mg/kg (collected from 1998 – 2001)

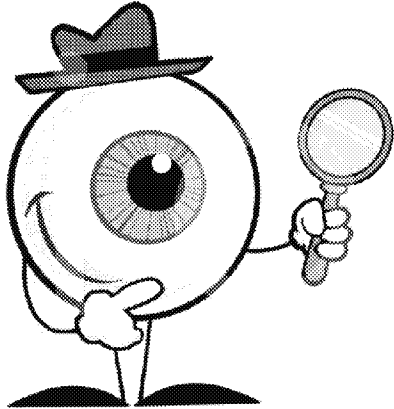
<i>Tank/Boring</i>	<i>Depth (ft) > 50 fbg</i>	<i>TPH mg/kg</i>
B-01	59.6	2,330
B-16C	60	9,400
B-14	60.5	2,090
B-14	60.5	2,810
B-01	61.35	3,300
B-16C	67	4,500
B-11	67.1	1,440
B-16A	83.75	6,600
B-16A	83.75	11,000
B-11	85	2,320
B-11	95	2,910
B-14	95.5	26,200
B-16A	101.83	2,800
B-12	121.9	1,710

LNAPL Range Concentrations in Vapor



Data compiled by Bob Whittier, source; Navy Soil Vapor Reporting

What Can We Surmise from All That?



- There is NAPL in boring samples under tanks
- There has been NAPL in/near groundwater
 - Observations of sheen & blebs (~2010)
- Concentrations in g.w. indicative of NAPL
 - Persistence in tank corridor wells
 - Periodic detections at Red Hill shaft
 - Peak concentration near solubility
 - Pattern consistent with LNAPL source area
 - * Also fast depletion – high flow regime/bio
- Data are internally consistent - conservatively
 - Fuel has potentially reached g.w. in the past
 - Distance of contaminant transport is large
 - Some residual capacity already occupied
 - Uncertainty due to data gaps; time/location



S.S. PAPADOPULOS & ASSOCIATES, INC.
ENVIRONMENTAL & WATER-RESOURCE CONSULTANTS

February 19, 2018

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105
Attention: Mr. Bob Pallarino

STATE OF HAWAII
DEPARTMENT OF HEALTH
P.O. Box 3378
Honolulu, HI 96801-3378
Attention: Fenix Grange, M.S., Program Manager

Subject: Comments on Presentation Materials from the Red Hill Groundwater Modeling Working Group (GWMWG) Meeting #7 and Status of Interim Modeling as Presented Associated with Administrative Order on Consent ("AOC") Statement of Work Requirements 7.1.3 (Groundwater Flow Model Report) and 7.2.3 (Contaminant Fate and Transport Report)

Dear Mr. Pallarino and Ms. Grange:

At the request of the U.S. Environmental Protection Agency ("EPA") and Hawaii Department of Health ("DOH"), collectively the "Regulatory Agencies", I am providing comments and suggestions regarding the status and progress of activities associated with Administrative Order on Consent ("AOC") Statement of Work Requirements 7.1.3 (Groundwater Flow Model Report) and 7.2.3 (Contaminant Fate and Transport Report), emphasizing materials presented at the Red Hill Groundwater Modeling Working Group (GWMWG) Meeting #7, January 11th, 2018.

First, it is important to acknowledge the progress in recent months on site characterization, data collection, and the evaluation of those data. The Navy and its contractors have been diligent in their efforts and much good work has been completed. Any evaluation of the potential risk posed by Red Hill fuel storage must be substantiated by extensive, high-quality data and associated analyses and in this context, the progress on data collection and analysis is welcomed. These data and analyses, together with independent information from prior local studies and analogous site studies, form the basis for the conceptual site model (CSM) that will underpin subsequent modeling.

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In addition, the development of the interim groundwater flow (capture) model presented to-date is in many respects of high quality, and consistent with the AOC and the anticipated progress of model development at this time. It was particularly encouraging to be recently presented draft particle tracking output based on the current interim groundwater flow model, which illustrated how the model when further developed can help assess the zones of contribution to water supply shafts as required by the AOC, and provide a basis for the final flow and transport models.

However, based on materials presented to-date, the CSM of Red Hill that is in development by the Navy appears over-simplified in its present form and appears to omit site-specific features and processes that are likely to play an important role in evaluating the risk posed by Red Hill fuel storage to potential receptors including Halawa and Red Hill shafts. Related to this, there are at this time simplifications in the development of the groundwater model that parallel concerns expressed above and below regarding the status of the CSM. While simplifications necessitated in the early stages of CSM and model development, and embodied in interim or "screening-level" analyses, are often assumed to be *de-facto* protective, the complex conditions at Red Hill offer no assurance of conservatism via simplification. Given this, the CSM and subsequent model development and application should be inclusive rather than exclusive until data and analyses might render undesirable outcomes sufficiently improbable; and, where data are absent or site conditions unknown, more conservative (i.e., protective) assumptions should be used.

Specific areas of concern are noted below, together with suggestions to remedy these concerns. Because G.D. Beckett (AQUI-VER, Inc.) is providing the Regulatory Agencies expertise on the evaluation of Non-Aqueous Phase Liquids (NAPL), the comments below emphasize the overall CSM and its relation to the groundwater flow and contaminant fate and transport models.

1. A priority in the development of the Red Hill CSM to support predictive modeling is a comprehensive 3-D evaluation and documentation of subsurface geologic conditions, emphasizing characteristics that influence flow, transport and fate. The Navy has stated that a 3-D geologic model has been developed based, in part, on local borings and plentiful if dated barrel logs from Red Hill. When developed to support groundwater flow and contaminant transport models, such a geologic model - incorporating evaluations of unit continuity, bedding and fracture strike and dip, and so on - can be an input basis for single or multiphase numerical models. The 3-D geologic model alluded to by the Navy may be detailed (which cannot be independently confirmed), but as noted below presently the geologic underpinnings of the groundwater model are not. Although assurances have been provided by the Navy and its contractors that these type of detailed site-specific features and processes are being considered, they have not been a focus of recent Navy presentations and it is unclear how they are to be represented and incorporated into the CSM so that it can underpin groundwater flow and transport models. If such has been completed already by the Navy, it should be presented or provided for review.
2. The groundwater and NAPL models presented at the GWMWG Meeting #7 currently rest on the assumption that the complex site geologic conditions can largely be treated as an

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equivalent porous media (EPM). This assumption is unlikely to be conservative (i.e., protective), and is not supported at relevant scales by the subsurface geologic data that already exist at and near Red Hill. At this stage of development, and absent data to the contrary, the Red Hill CSM should incorporate a high likelihood of high lateral continuity of features that facilitate flow and transport. Having incorporated these more conservative assumptions in the Red Hill CSM and subsequent groundwater and NAPL models, in the event that they result in potentially unacceptable impacts to receptors, any additional field characterization and data collection can focus on obtaining information to corroborate or refute these conservative assumptions.

3. In regard (2), development of the CSM appears to have emphasized some features that may be of limited significance to the evaluation of risk, while placing less emphasis on features and processes that are likely of greater significance. For example, emphasis placed on recharge from the nearby quarry may outweigh its influence on groundwater flow and contaminant transport within underlying basalts. [*During a January 12th meeting at the quarry attended by the Regulatory Agencies, information was provided suggesting that return-flow (non-consumptive use) may be substantially less than presumed.*] in anticipation of the fate and transport analyses to come, greater attention should be given to the likely impact of basalt stratigraphy on flow, transport and fate. At this stage of the AOC and development of the Red Hill CSM, it is more appropriate to assume that intervening recharge sources and saprolites are not inherently protective until data and analyses can better inform these assumptions.
4. At present, the groundwater model represents major (first-order) Hydro-Stratigraphic Units (HSUs) – e.g., differentiating basalt from saprolite from carbonates – but does not differentiate within these HSUs (in essence assuming the subsurface can be represented as an EPM). Studies from other basalt regions, however, indicate a high potential for connected flow-paths that can enhance migration distances and rates versus EPM assumptions: and, though few controlled experiments are published for conditions directly analogous to Red Hill, studies in simpler environments show heterogeneous migration even under ideal conditions. At Red Hill, the documented geology, stratigraphic exposures in the nearby quarry, and variable hydraulic gradients indicate the subsurface is more complex than the current CSM and groundwater model represent.
5. The upgradient (i.e., northeastern mountain-front) boundary condition of the groundwater flow model may exert a strong influence on flow and migration patterns, acting to enhance or perhaps over-prescribe the propensity for flow to occur *Mauka to Makai* regardless of other factors such as recharge and pumping. This boundary condition (in concert with the lateral boundaries) should be viewed with caution and evaluated via calibration-constrained sensitivity analyses. This situation may have been reflected in the water budget analysis presented at the GWMWG Meeting #7, where the assumption of low spring flow

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in 2015 at time of relatively high recharge seems counterintuitive and may suggest that the assumption of constant inflow along the mountain front may be erroneous.

6. Although instructive as an introduction to and illustration of relevant concepts and terms, the NAPL evaluation presented at the GWMWG Meeting #7 appears so simplified as to have uncertain or limited future application. The calculations appear to suggest little to no potential for groundwater impact, whereas available data appear to contradict this. The current Navy NAPL evaluation requires substantial enhancement to provide further utility in the coming quantitative evaluation of risks posed to potential receptors.
7. With regard the transition from an interim capture zone model to detailed analyses of contaminant fate, transport, and associated risk: while the work presented at the GWMWG Meeting #7 is being performed in the context of interim model development in accordance with the AOC, the approach may not yet be sufficiently comprehensive to inform tank upgrade decisions or evaluate risk. Recognizing that models are imperfect representations of the world, simplifying assumptions used to-date in the development of the Red Hill CSM, groundwater flow model and NAPL assessment could lead to over-simplified fate and transport analyses. To remedy this, the Navy should present the technical approach(es) under consideration to represent the complex subsurface conditions at Red Hill in the CSM and derived predictive models. A wide range of possibilities exists, and only a couple examples are suggested here, such as:
 - a. When considering zones of contribution to supply shafts, the use of advective-dispersive rather than solely advective pathline analyses can be instructive.
 - b. The dual domain formulation may be suitable for initial mass-conservative transport simulations as an alternative to discretizing the flow model at the scale of connected conductive features, although the MODFLOW-USG code selected by the Navy is ideally-suited to refinement in areas of interest and structure-imitating methods could be used to represent and parameterize the basalt geology.

Whatever approach the Navy ultimately adopts to represent greater site-specific hydrostratigraphic and transport detail, the developed models must support realistic flow, transport, fate and risk analyses. As the development of the interim model nears completion, the Navy should present an evaluation of the appropriate scale for discretizing the groundwater flow, fate and transport models to adequately represent site conditions.

Given the requirements of the AOC, the intended applications of the groundwater flow and fate and transport models to evaluate scenarios and risk, and the reliance of these analyses on a site-specific CSM, it is likely that the models will combine locally-detail and fine discretization with regionally-simplified parameterization and discretization so that sensitivity and predictive analyses can help evaluate whether there are conditions that are consistent with the data under which an unacceptable impact could occur. The CSM and derived models will over time benefit from further data collection to help confirm or refute underlying conservative assumptions

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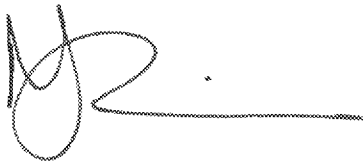
implemented to provide for protectiveness. Whether and to what extent additional characterization may be necessary is presently difficult to gauge without understanding to what extent existing data have been incorporated into the Red Hill CSM and derived models. If the CSM and derived models incorporate features and processes at appropriate scales, then the necessity for and extent of any additional characterization may be informed via calibration-constrained sensitivity and predictive analysis. If the CSM and derivative models are, however, too simplified, then the models may not provide the benefit to the project that they could be capable of.

In summary, while the progress made by the Navy and its contractors is encouraging, and it is recognized that development of a comprehensive CSM and derivative predictive models must of necessity follow a systematic process of steadily incorporating site-specific complexity, at this time the Red Hill CSM appears over-simplified and it is unclear how site-specific subsurface complexity will be incorporated in a manner supportive of the pending fate and transport analyses.

Please feel free to contact me if you have any questions regarding the foregoing concerns.

Sincerely,

S. S. PAPADOPULOS & ASSOCIATES, INC.

A handwritten signature in black ink, appearing to read 'MT', followed by a horizontal line extending to the right.

Matthew J. Tonkin
President

Pallarino, Grange
February 19, 2018
Page 6

Reference Materials:


- (1) January 11, 2018. Groundwater Flow Model Working Group Meeting No. 7, Red Hill Bulk Fuel Storage Facility. Slide handout materials pp. 1 - 150.
- (2) September 1, 2017, Revision 00. Conceptual Site Model Development and Update Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility. Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i. Administrative Order on Consent in the Matter of Red Hill Bulk Fuel Storage Facility, EPA Docket Number RCRA 7003-R9-2015-01 and DOH Docket Number 15-UST-EA-01, Attachment A, Statement of Work Section 6.2, Section 7.1.2, Section 7.2.2, and Section 7.3.2.
- (3) April 2017, Revision 00. Data Gap Analysis Report, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility. Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i. Administrative Order on Consent in the Matter of Red Hill Bulk Fuel Storage Facility, EPA Docket Number RCRA 7003-R9-2015-01 and DOH Docket Number 15-UST-EA-01, Attachment A, Statement of Work Section 6.2, Section 7.1.2, Section 7.2.2, and Section 7.3.2.
- (4) July 2017, Final. Second Quarter 2017 - Quarterly Groundwater Monitoring Report Red Hill Bulk Fuel Storage Facility. Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i. DOH Facility ID No.: 9-102271, DOH Release ID Nos.: 990051, 010011, 020028, and 140010.
- (5) Sanford, W. E., L. Niel Plummer, G. Casile, E. Busenberg, D. L. Nelms, and P. Schlosser (2017), Using dual-domain advective-transport simulation to reconcile multiple-tracer ages and estimate dual-porosity transport parameters, *Water Resour. Res.*, 53, 5002–5016, doi:10.1002/2016WR019469.
- (6) Liu, Y. and P. K. Kitanidis, 2012, Applicability of the Dual-Domain Model to Non-Aggregated Porous Media, *Ground Water*, 50(6): 927-934.
- (7) Liu, G., C. Zheng, and S. M. Gorelick, 2007, Evaluation of the applicability of the dual-domain mass transfer model in porous media containing connected high-conductivity channels, *Water Resources Res.*, 43, W12407, doi:10.1029/2007WR005965

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February 16, 2018

Memo To: Fenix Grange
Hawaii Department of Health
Lindsey Tu
EPA

From: Donald Thomas 
HIGP
Robert Whittier
Hawaii Department of Health

Subject: Perspectives on the Trajectory of AOC Discussions up to the Present Time

We offer our comments in two parts: in the first, we comment on where the current process has not been optimally productive; in the second, we summarize the hydrogeology questions that we believe need to be answered in order to have a defensible risk assessment.

I. Past Interaction with AECOM/GSI

The pattern of presentations in the face-to-face meetings has been to: 1) outline one or more work tasks that are proposed and being pursued; 2) a presentation of a summary of the data acquired from those tasks that have been completed; and 3) a set of assertions are made as to what the data are showing. When questions are raised about those assertions, they are noted, but, in subsequent meetings, there is little time made available, or effort made, to provide a full accounting of how the assertions were arrived at or to address any contrary data that don't support the assertions. Stated very briefly we are being presented with: "This is our theory of the conceptual site model, and these are the data that support that model... the end."

Salient examples of this practice are:

The proposed geologic conceptual site model was, allegedly, developed on the basis of the well core data and the barrel logs, with very large, contiguous zones of a'a/clinker and pahoehoe stratigraphic layers extending thousands of feet laterally and many tens of feet vertically. We know that these lava flow types, individually, usually extend by a few tens of feet laterally and vertically, and are distributed almost randomly (at any particular elevation) across the surface of a volcano as it resurfaces itself. **We have requested documentation to support the proposed stratigraphic model repeatedly, but there has never been a detailed presentation of that data or how it was used to create the proposed model.**

The proposed groundwater flow model has shown water flow from mauka to makai in the area of Red Hill Ridge. The recent resurvey of the wellhead elevations has shown a nearly flat groundwater gradient within the monitoring wells up the ridge. **It has been repeatedly pointed out that, for that flow model to be supported, there needs to be an observable groundwater gradient in that same direction, but the model presented by AECOM remains little changed from that developed by Rotzoll and El-Kadi for the 2007 Red Hill investigation that suffered from the same weakness.**

Data have been provided to the Navy contractors on the chemical and isotopic compositions of the groundwater throughout their monitoring well network and much of Oahu. Those data show very significant variations in the ion compositions as well as the isotopic ratios in the Red Hill area that are as large as, or larger than, the entire Oahu dataset. That strongly suggest spatially disparate sources of recharge into the area of investigation and highly variable, and spatially complex, mixing of water in closely spaced wells. The Navy contractors have interpreted the data to indicate a smooth and contiguous mixing of saline and fresh water even though their cited mixing line indicates a flow path that, in no way, resembles their proposed groundwater flow directions. **We have repeatedly questioned this interpretation and requested that they present the underlying logic of their proposed mixing, but have not received a satisfactory answer while they still propound their original interpretation.**

In the recent presentation of the seismic survey work, the results of processed reflection/ refraction data were presented, along with an interpretation of those results with respect to the depth to the bottom of the alluvium and saprolite layers within the valleys. It was noteworthy that, in nearly every case, the deepest reflector was designated as the base of saprolite. The individual presenting the results on behalf of AECOM was not the subcontractor who collected the data and was clearly not qualified to answer our questions regarding: how those interpretations were arrived at; any uncertainties in the depiction of the results; or AECOM's plans to further validate the interpretation presented. **This was a first presentation of these data and interpretations; it remains to be seen if we will receive more detailed responses to those questions posed during the presentation.**

Without detailed discussions among the respective contractor and regulatory agency SMEs of:

- 1) what data were used;**
 - 2) what and why available data were excluded from use; and**
 - 3) the underlying logic of incorporation of the data**
- in the development of the proposed CSM and flow models, I don't believe that we can, or should, accept the models proposed.**

II. Critical Questions that Need to be Addressed in a CSM and Flow Model

In the discussions to date, the focus has been largely operational. From the contractors: "this is the information we need to develop a CSM and a flow model and this is how we will gather it." But there is no clear definition of how the information derived from the tasks relates specifically to the objectives of the risk assessment; nor are there any metrics as to whether the requirements of the risk assessment are being credibly met.

I believe that the hydrogeologic processes involved in the release and transport of the LNAPL and dissolved contaminant (which are key to the overall risk), can be parsed into a set of specific questions that need to be adequately answered by the Navy contractors in order to have a defensible risk assessment. A partial list (with additions by other SMEs to be added) of the questions relevant to contaminant transport are detailed below. I believe that these questions can provide better focus to the work being conducted ("this work task will provide these data to answer this, or these, questions") and will allow the regulators to evaluate whether that work can produce the needed answers and whether the data, once generated, has provided credible answers that can be accepted.

- 1) What is the direction of LNAPL flow in the vadose zone for a range of possible release scenarios? (With respect to the latter, we, and the contractors, need to have input from the Navy on what their consultants believe is an realistic range of release scenarios in terms of locations, volumes, and rates.)
 - 1a) How does the fuel interact with the stratigraphic sequence?
 - 1b) How much of the fuel is tied up in the solid phase?
 - 1c) How does the state of water saturation of the porous media affect its ability to hold up the LNAPL phase?
 - 1d) What is the interaction of rainfall recharge with the retained fuel in the formation?
 - 1e) How does natural attenuation affect the residual fuel held up in the formation
- 2) Once the LNAPL reaches the water table where does it go (how great a threat does it pose to groundwater wells)?
 - 2a) How far does it spread?
 - 2b) In what direction is spreading favored?
 - 2c) Does the LNAPL interact with geologic structures/obstructions differently from water and, if so, how?
 - 2d) How does pumping affect the spread of the LNAPL?
- 3) As the LNAPL components dissolve into groundwater, how does that contaminant plume move (how great a threat does the dissolved contaminant plume pose to drinking water wells)?
 - 3a) What is the natural direction of water flow within and around the Red Hill ridge?
 - 3b) How much of what dissolves?
 - 3c) How, if at all, does the dissolved phase chemically interact with the stationary phase (rocks/alluvium/saprolite)?
 - 3d) What role does natural attenuation play in removing the dissolved constituents?
 - 3e) How does pumping affect movement of the dissolved phase?
 - 3f) How does the dissolved phase interact with the natural obstructions (e.g. valley fill/saprolite within the water table) within the stratigraphic matrix through which the water flows?




STATE OF HAWAII
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In reply, please refer to:
File:

February 20, 2018

TO: G. Fenix Grange, M.S., Program Manager
Hazard Evaluation and Emergency Response Office

FROM: Robert Whittier, Source Water Protection Geologist
Safe Drinking Water Branch 

RE: **Comments on the Progress of the Red Hill Groundwater Flow Model**

For a groundwater model to be acceptable as a risk assessment tool, the simulated groundwater elevations, and more specifically simulated groundwater gradient, must be in close agreement with what is measured within the area of concern. The Red Hill Facility underground storage tanks (USTs) straddle the boundary between the Pearl Harbor and Honolulu Aquifers. Relative to this boundary, the Halawa Shaft, the largest and most important public drinking water source in the State of Hawaii, lies to northwest of this boundary and within the Pearl Harbor Aquifer. Knowledge of the hydraulic relationship between the Honolulu and Pearl Harbor Aquifers is critical to assessing the risk that a large release from the Red Hill Facility USTs pose to public drinking water sources.

Five (5) important things that we already know:

1. In the absence of a barrier, groundwater flows from areas of higher hydraulic head to areas of lower hydraulic head.
2. The hydraulic head in the Moanalua area of the Honolulu Aquifer is about 1 ft higher than the hydraulic head beneath the Red Hill Ridge, and the Hydraulic Head beneath the Red Hill Ridge is about 1 ft higher than that at the Halawa Shaft (in the Pearl Harbor Aquifer) when the pumps are off (the difference is much greater during normal pumping operations).
3. There is no measurable gradient within the wells of the Red Hill Monitoring Network (RHMN) that are located beneath or near the axis of the Red Hill Ridge. With RHMW04 being the most upslope well and RHMW05, the most downslope well prior to the Red Hill Shaft. The wells; RHMW04, RHMW03, RHMW02, RHMW01, and RHMW05 represent a linear distance of about 0.7 miles, and essentially define a groundwater contour.
4. There are four wells in the RHMN to the northwest of the boundary between the Pearl Harbor and Honolulu Aquifers. Two of these wells, RHMW07 and HDMW2253-03, have groundwater elevations higher than that of the wells described in bullet 3. However, the water level in RHMW07 is anomalously high, four feet higher than the other wells in the RHMN and shows very poor connectivity to the aquifer. HDMW2253-03 is a deep monitoring well with an interval that is open to the aquifer for greater than 1000 feet. The water level measured in this well is integrated over the 1000 feet open interval bringing into question how reliable this well is in assessing the groundwater elevation at the top of the aquifer.

5. Wells RHMW06 and RHMW08 are water table wells and also to the northwest of the USTs. These wells have water levels that are lower than those in the wells described in bullet 3. The above observations taken as a whole indicate that groundwater flow from the Honolulu Aquifer, beneath the USTs and toward the Halawa Shaft in the Pearl Harbor Aquifer has to be considered probable until conclusively shown otherwise.

The model results presented in the February 12th Red Hill Groundwater Modeling Working Group (RHGWMWG) meeting show groundwater elevation patterns much different from those measured. For example Slide 24 from the February 12 RHGWMWG meetings shows that the simulated water level near RHMW05 is about a foot lower than that at RHMW02, much different than what is measured. In fact this infers a gradient of more than 3 feet per mile, rather than the flat gradient that is consistently measured. More importantly, for the Red Hill Shaft zone of contribution shown in Slide 57 to be valid the relative groundwater elevations simulated by the model within that zone of contribution should be in close agreement to those measured in the field.

The bar graph below compares the modeled groundwater elevations (blue bars) to those measured in 2017 (orange bars). The data are arranged going from RHMW04, the most upslope well, to OWDFMW01, the most down slope well. A visually estimated trend line is drawn for each data set. The values for the modeled groundwater elevations were derived by applying the modeled residuals in Slide 30 to the average of water level measurements during the July and November rounds of groundwater sampling. For the modeled capture zone shown on Slide 57 to be valid there should reasonable agreement between the trend in the modeled and measured groundwater elevations. Clearly this is not the case, and the presented model is essentially no better than that of Rotzoll and El-Kadi the Red Hill investigation is tasked to improve upon.

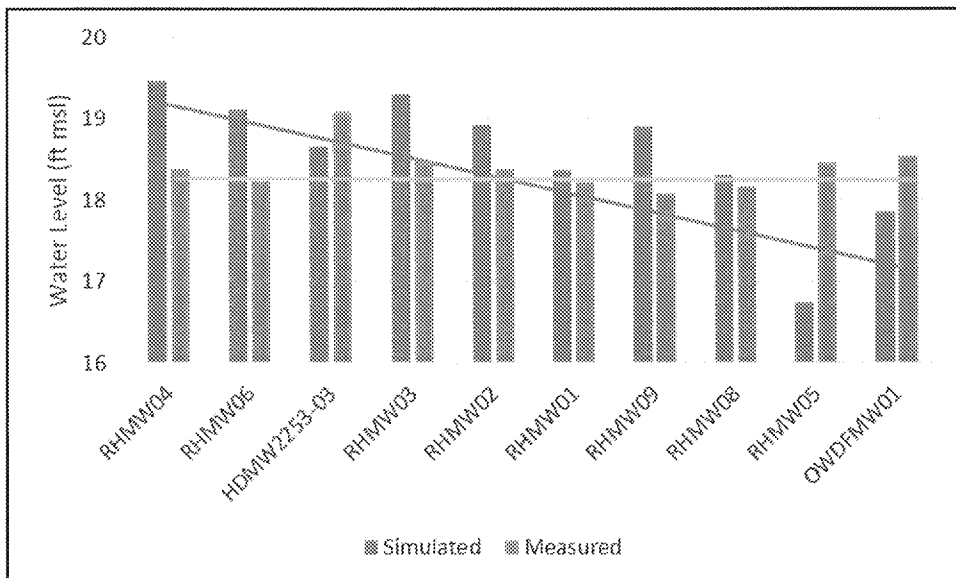


Figure 1. A comparison of the simulated and measured groundwater elevations in the RHMNW. RHMW07 is excluded from this graph since the water level in this well is very anomalous. The Red Hill Shaft (2254-01) is also excluded due to questions about the top of casing reference

point and this is an actively pumped well making the measured water levels not reflective of that in aquifer.

If the zone of contribution for the Red Hill Shaft is in error, then likely that for the Halawa Shaft is also in error. Also, the data need to be presented in such a way that reviewers can easily determine whether or not the conditions for model validity are met. The calibration graph shown in Slide 26 does not provide sufficient information to allow an assessment of model validity. It also appears that wells on the extreme greatly improve the appearance of correlation between the simulated and measured water levels but may not appropriate for this purpose.

In summary, for the groundwater flow model to be acceptable as a risk assessment tool, there must be much better agreement between the simulated and measured water levels in the critical areas. These areas are the Moanalua area wells, the RHMNW wells, and the wells in the Halawa area.